The
ENGINEERS' DIGEST

REVIEW OF WORLD ENGINEERING PROGRESS

VOL. XVIII No. 6

JUNE, 1957

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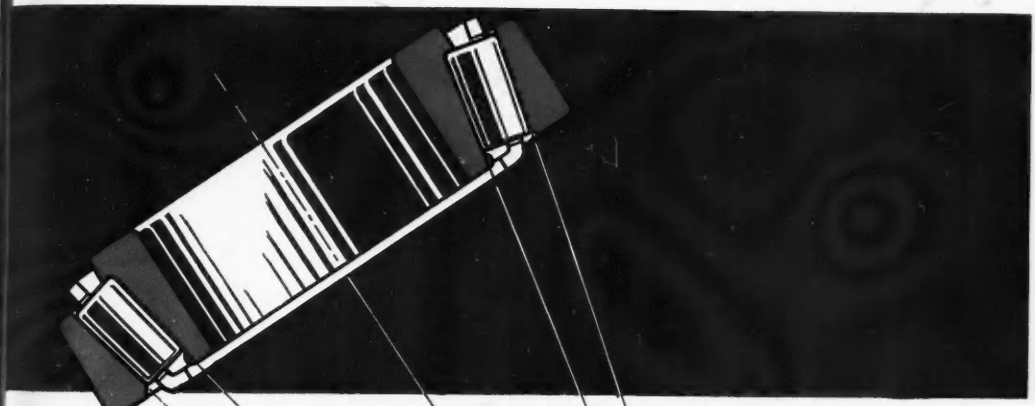

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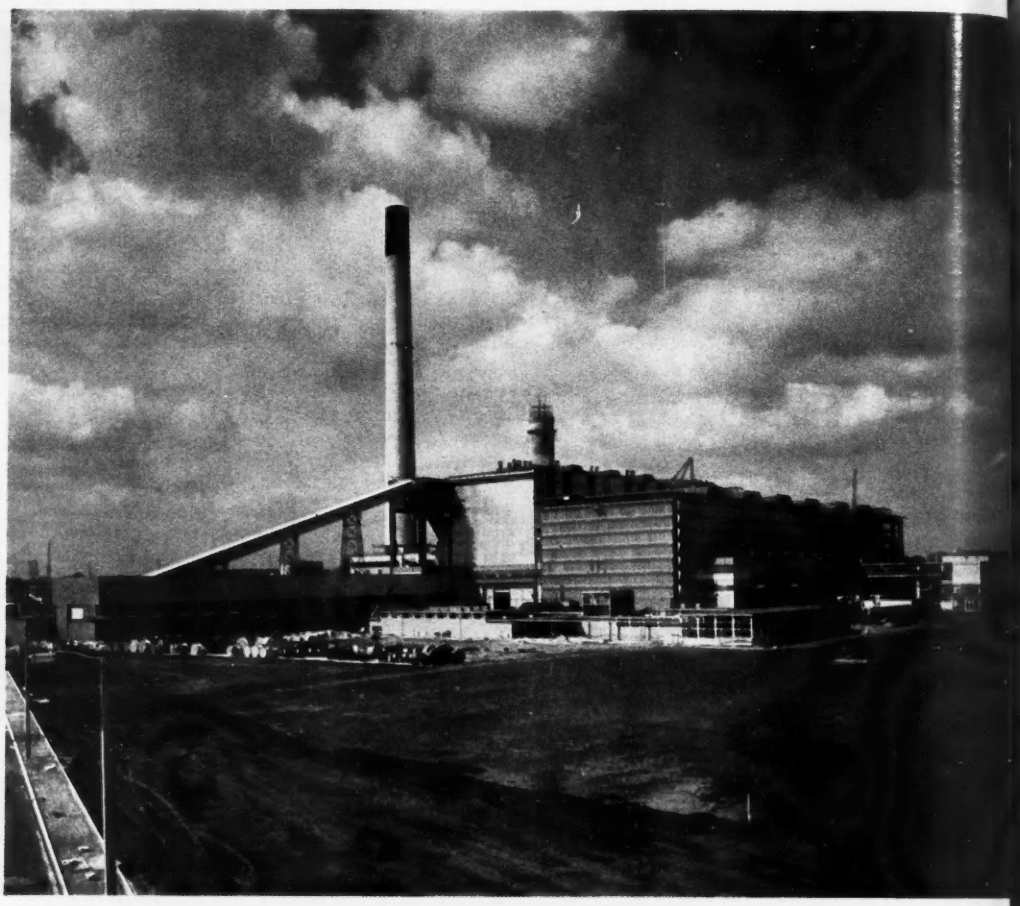

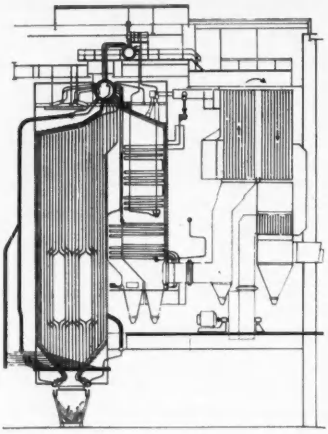

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THE BLUE PAGES

A QUICK GLANCE AT THE LATEST TECHNICAL DEVELOPMENTS THROUGHOUT THE WORLD

● *CORING SMALL DUCTS IN CASTINGS*

A novel coring method for obtaining small passages in the production of non-ferrous castings has been evolved, in which use is made of a core consisting of a preformed metal tube sheathed in a flexible refractory sleeve. Both tube and sleeve are removed after casting. The metal tube is removed chemically, and the sheath can then easily be removed by hand. Aluminium- and magnesium-alloy castings are stated to be unaffected by the chemical used for dissolving the tube. The sheathed-tube core is used in combination with ordinary sand cores, and is employed for making passageways which are impossible to make with sand cores, or when ordinary sand cores would be more expensive. The minimum practical sand core is about $\frac{1}{4}$ in. in diameter, as any core smaller than this would break too easily. Sheathed-tube cores are rigid and stable, and passageways as small as $\frac{1}{8}$ in. are reported to be common. The smallest sizes can be 16 in. long. Larger core diameters can be cast in greater lengths, and it is reported that, in one instance, a sheathed core, $\frac{5}{16}$ in. in diameter and 4 ft long, has been successfully used. There are few limitations with regard to direction, and shapes can be matched to the contours of a casting. With this method, therefore, passageways for oil, fuel, coolant, and hydraulic fluids can be wrapped (internally) around a large cylinder in a continuous length. In this way the need for exterior fluid lines and the bosses and drilling operations normally required are successfully eliminated.

● *GLASS-LINED PUMP FOR CORROSIVE LIQUIDS*

A glass-lined centrifugal pump for corrosive liquids has been developed, it being claimed that, by bonding glass to all exposed surfaces, the pump is suitable for a wide range of acids and alkalis. Successive applications and firings fuse the glass permanently to the iron and develop high mechanical strength and resistance to thermal shock. Products will not adhere to the glass surface, and no catalytic effects occur in any known process. The casing is made in three sections, so that all surfaces can be reached to apply the glass. The suction flange, discharge casing, and casing cover are lined on all surfaces which contact liquid, and bolted joints are sealed by gaskets with thin Teflon envelopes. This three-piece construction has the added advantage that it can be assembled with discharge and suction flanges in various positions, to suit existing piping arrangements. Before the glass is applied, the castings are examined, and all rough spots are ground smooth. The corner radii are so chosen that proper coating thickness is maintained at contour changes. Powdered glass in a water suspension is sprayed onto the metal and is then fired at a high temperature, several coats being applied and fired individually to obtain the desired thickness. A high structural strength of the glass coating results from the chemical bonding of glass and iron while hot, and also from the compressive stresses which develop in the glass as the part cools. The impellers require a special processing, as all surfaces must be glassed. The glass thickness is controlled to obtain proper clearances between moving parts and to allow dynamic balancing of the impeller before the glass is applied. The glass coating on the impeller shaft is carried beyond the seal and is ground smooth to prevent leaks. With this design, the rotating member has no internal joints in contact with the liquid. It is stated that clearances between impeller and casing are greater than in metal pumps, but the effect on the hydraulic efficiency is balanced by the lower friction losses with the glass surface.

● *HIGH-TEMPERATURE BALL BEARINGS*

As a result of recent developments in machine tools, aircraft engines, aircraft accessories, and nuclear power plants, new problems in ball-bearing design have arisen. Novel designs of equipment are continually demanding smaller bearings to carry heavier loads at higher speeds and higher temperatures, and in some cases to operate in a corrosive and/or non-lubricating medium. While to-day there are only a few commercial applications for bearings operating above 450°F, several designs are being developed which will require bearings to operate above this temperature. Standard ball bearings, with ordinary steel stabilized for temperatures up to 450°F, have been in successful use. However, at temperatures above 300°F, structural and dimensional changes occur, owing to transformation of martensite, and the rate of change increases with the temperature. As a result, bearing capacity and life are decreased. Mater-

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ials showing the greatest promise for temperatures up to 900 to 1000°F are the high-speed tool steels, which have good hot hardness, dimensional stability, and high-temperature strength, because of their tungsten, cobalt, molybdenum, and vanadium contents in various proportions. Corrosion-resistant materials are required for operation in pressurized water at temperatures up to 600°F, in air or inert-gas temperatures up to 1600°F, and in corrosive gases at various temperatures. Since, in these cases, lubrication other than the operating medium is generally not possible, compatibility and wear resistance are important requisites. Cobalt-chromium-base, nickel-base, and copper-base alloys have all been used for such applications, in some cases with good, and in others with marginal, results.

● *MINIATURE SELENIUM RECTIFIER*

The trend towards miniaturization of electronic gear has been accompanied by the development of miniature secondary storage batteries ; this, in turn, has created a demand for equally small rectifier equipment, which is being met by the production of point-contact selenium-rectifier equipment with very small areas. Units of this type, arranged as half-wave or full-wave rectifiers, are now being supplied in compound-sealed form, providing exceptional robustness and insensitivity to adverse ambient conditions, such as moisture-laden air. For special applications, complete units weighing as little as 1 gram can be supplied. With a maximum forward current of 40 mA the specific loading is some 250 mA/cm², with a maximum reverse voltage of 20 V. The capacitance of these rectifiers decreases sharply with the voltage, up to about 10 V ; it is also frequency-dependent, being some 15% smaller at 100 kcs than at 700 cps. In pulse-generator applications, pulses of 250 mA, with a pulse length of 1μsec and a pulse repetition rate of 100 kcs, can be obtained. An interesting application of these rectifiers is that in conjunction with miniature storage batteries for hearing aids, eliminating the need for frequent replacement of batteries.

● *NON-DESTRUCTIVE TESTING OF NUCLEAR-REACTOR FUEL ELEMENTS*

A number of non-destructive tests have been developed and used to ensure a high degree of reliability of the fuel elements employed in nuclear reactors, one of these being the isothermal frost test. Areas of the clad showing relatively lower heat-transfer rates because of lack of bonding or flaws may be detected by this test, in which the relative rate of heat transfer from a uniformly heated surface (the clad) to the uranium metal is determined. The frost test consists of spraying the canned fuel element with a 14% solution of acenaphthene or a 40% solution of diphenyl in carbon tetrachloride, leaving a rough or frosted surface. The specimens are then moved at a uniform speed through an induction heating coil by a conveyor system. Eddy currents are induced in the outer portions of the element, especially in the aluminium jacket. With the proper rate of heat generation and movement of the specimen through the heating coil, the major portion of the heat flows inwards through the jacket and the alloy bond into the uranium core, which serves as the thermal sink. An unbonded area or a flaw in the bond results in a thermal barrier, and the jacket over this area is heated above the melting point of the frost, which melts to form a smooth surface outlining the defective area. Visual inspection may be carried out at a convenient time, even up to several days. The so-called thermographic method is an improvement on the isothermal frost test. In this test, a temperature-sensitive phosphor is applied as a paint on the test specimen. One such zinc-cadmium sulphide phosphor, when irradiated with ultraviolet light, will change its emissivity by 20% when its temperature is varied by 1°C.

● *BRAZING ALLOYS RESISTANT TO SODIUM ATTACK*

The fabrication of heat-exchanger equipment for high-temperature service presents exceedingly complex problems, since rigid heat-transfer requirements necessitate the use of compact assemblies of thin-walled, small-diameter tubes. Intricate designs may also be required in which fins must be securely joined to the tubes at closely spaced intervals. In addition to the difficulties in fabrication imposed by the designs themselves, the high operating temperatures involved require the careful selection of materials and joining techniques. The choice of fabrication procedure for a given component must be based not only on the stresses and temperatures to be encountered, but also on other special factors. The use of liquid-metal coolants, such as sodium, requires excellent compatibility of the structural materials with these corrosive media. Although welding is used extensively in the construction of the extended-surface equipment, high-temperature brazing is also attractive for several applications. A recent paper presents a summary of the resistance to corrosion and oxidation by sodium of many alloy systems which have been investigated and developed in recent years. In the corrosion testing of brazing alloys in various heat-exchange fluids, two testing techniques are employed, i.e., the static and the "seesaw" test. The static method is very simple and permits the rapid screening of large numbers of brazing alloys. The seesaw method, on the other hand, is a dynamic corrosion test

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in which the testing medium is kept in motion by oscillation of the furnace. Test results indicate that alloy systems of the Ni-Si-B, Ni-Cr-Si-B, and Ni-Cr-Si types possess excellent resistance to sodium attack. Precious-metal alloys are, in general, severely attacked by sodium. Alloys containing manganese, tin, or copper have poor resistance to oxidation by sodium at 1500°F.

● *ULTRA-MINIATURE TELEVISION CAMERA WITH AUTOMATIC IRIS CONTROL*

Basically developed for military airborne, mobile, and field closed-circuit television applications, a new ultra-miniature television camera combines the use of transistors, specially developed transistor circuitry, and a new ½-in. vidicon camera tube. Weighing less than 1 lb and measuring only $1\frac{7}{8} \times 2\frac{3}{8} \times 4\frac{1}{2}$ in., the camera is stated to surpass standard vidicon-type industrial cameras in sensitivity, and with an F:1·9 lens requires only 10 foot-candles of scene illumination for clear, contrasting pictures. It is also the first camera of its type to incorporate a photoelectric iris control, which automatically activates specific camera circuits to compensate for changing light levels, and which enables the camera to accommodate changes of the order of 100 to 1 in scene lighting. Operation is exceptionally simple, and no technical skill is required, since control adjustments are rarely needed, once optical and electrical focus have been fixed for a specific application. In addition to being used on a tripod, the camera can be held in the hand and operated with a special pistol-grip handle. A high level of resistance to shock and vibration, combined with maximum power economy, is another feature. The camera system operates from a 115-V, 60-cps a.c. source and draws less than 350 W, camera dissipation being only 3 W. By virtue of its exceptionally reduced size, simplicity, and flexibility, it should open up new fields of application for closed-circuit television, permitting direct observation in locations hitherto inaccessible to existing television equipment.

● *WOVEN-GLASS FOIL FOR DIMENSIONALLY STABLE PHOTOGRAPHIC PAPER*

For measuring purposes, and especially in photogrammetry, a dimensionally stable photographic paper is used, in which a metal foil lined with paper forms the layer support. Owing to its low weight, aluminium foil has proved to be particularly suitable for this purpose. It is, however, frequently necessary to make exposures by the reflex copying process on a dimensionally stable photographic paper, and this is impossible with lined metal foils, as the foil is not transparent. It has now, however, been found possible to produce reflex copies on a dimensionally stable paper in which a woven-glass foil lined with paper is used as a support for the light-sensitive layer, and it is claimed that the dimensional stability of this woven-glass foil is not in any way inferior to that of aluminium foil. Moreover, this foil is sufficiently pliable and offers the advantage of being highly resistant to the chemical action of photographic processing baths. For lining the woven-glass foil it is possible to use a wide range of papers, such as lacquer-coated papers, or papers which contain additives. The glass foil can, if desired, be lined with transparent paper on one or both sides. For improving the adhesion of the paper to the foil the latter is treated with a suitable impregnation agent, such as an aqueous dispersion of a high-molecular synthetic resin, which may contain plasticizers. These dispersions are coated on the glass foils, part of the solvent is evaporated, and the paper can then be lined with the impregnated glass foil. It is also claimed that, when using a woven-glass foil lined with paper, the operation of coating with light-sensitive layers, especially silver-halide emulsion layers, is considerably simplified.

● *WATER CRAFT WITH AUTOMATICALLY CONTROLLED HYDROFOILS*

A recent invention aims at the improvement of hydrofoil-equipped water craft in which the hydrodynamic lift of the hydrofoils is automatically controlled. The control arrangement serves to increase the seaworthiness of the vessel, particularly in a following sea, and to reduce its movement at sea in general, this being equivalent to reducing the number of impacts on the hydrofoil system. Fluctuations in hydrodynamic lift, produced on the hydrofoils partly immersed in the water, not only because of differences in depth of immersion but also because of the orbital motion of the water in the waves, cause considerable alterations in the approach angle. It is stated that the action of the sea in general and that of unfavourable wave conditions in particular can hardly be overcome by rigid hydrofoils. The invention therefore envisages the use of hydrofoils in which lift is automatically controlled in accordance with wave cycles and amplitudes. In the proposed control system the fluctuations in the lifting force, which can be taken up at the hydrofoil suspension, are used as the signals for controlling the means of varying the lift. Consequently, the system employed differs fundamentally from the stabilizers used on ships, which utilize the rolling and pitching movements of the ship as the control signals for actuating the stabilizers. In the proposed arrangement the hydrofoils are made vertically displaceable by spring action, which maintains equilibrium of the lifting force, the oscillations produced being used to control the pitch of the hydrofoils.

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● *IMPULSE BREAKDOWN OF ELECTRICALLY PRESTRESSED POLYETHYLENE*

Most available data on the dielectric strength of polyethylene are derived from laboratory tests conducted with very special electrodes under highly artificial test conditions. It is therefore of great interest to note the results of a recent extensive study of the breakdown of commercial polyethylene with plane electrodes, which approximate to conditions found in practice. An analysis of these data reveals that the statistical theory of extreme values can be applied in this case. Particularly noteworthy is the observation that, to a high level of statistical significance, electrical prestressing of polyethylene by reduced-voltage impulses increases the impulse breakdown strength of the material, and several hypotheses are suggested as an explanation of this phenomenon. Three of these appear to deserve particular consideration. The first appears to be the possibility that an electrode-conditioning effect takes place, similar to that found in breakdown studies with gases, liquids, and solids. This hypothesis is supported by the observed increase due to prestressing of the mean statistical time-lag, although this is very small. The second hypothesis suggests a phenomenon akin to polarization in its net effect, as a result of the formation of clouds of trapped charges in the dielectric. The third hypothesis is that a repair of structural defects in the material is effected by charges which have been rendered temporarily mobile by the impulse field. This appears to be the most plausible explanation of all, because of the marked increase in formative time-lag, suggesting that the prestressing has repaired defects in the material, making it less a semiconductor and more an insulator. Further investigations are planned to provide the final answer.

● *APPLICATIONS OF ELECTROLUMINESCENCE*

In electroluminescence, light is emitted by phosphors excited by an alternating field produced by an applied voltage. By proper choice of phosphors, a wide variety of colours can be obtained in electroluminescent cells, including blue, green, yellow, or red, and, by blending these materials, white light can be produced. Brightness of the electroluminescent cell is affected by frequency, and also by voltage, and an increase in either of these factors increases brightness. The fact that some phosphors are available which change in brightness with frequency suggests a method of varying the colour of an electroluminescent cell. A cell can be constructed with two different phosphors, one with an output increasing rapidly with frequency, and the other relatively unaffected by frequency changes. At low frequencies the colour output is then dominated by the first phosphor but, as frequency is increased, the colour of the second predominates. The phenomenon of electroluminescence has many other interesting potentialities. Thus, for example, electroluminescence offers a possible means of " picture-framing " television, and an electroluminescent cell might replace the conventional cathode-ray tube in such a set. Many possible applications of electroluminescence result if it is combined with a light- or radiation-sensitive device such as a photoconductor. These electrophosphor-photoconductor combinations are of interest for signal storage and other functions in modern electronic computers, where they can serve as logic " and ", " or ", " not ", and " nor " function elements. Their greatest present disadvantage in this application is their low speed of response, which is due to the characteristics of currently available photoconductors. It is, however, possible that a way will be found to alleviate this difficulty.

● *THE EFFECT OF ATMOSPHERIC MOISTURE ON ELECTRODE BURN-OFF RATES*

Arc welding in natural-air atmospheres is subject to variations in atmospheric water-vapour content. It is known that water in the air or electrode coatings has some effect on the welding process, so that specifications for some electrode coatings include a limiting requirement in regard to water content. Also, it is known that difficulty can be experienced in holding a welding arc in air in very humid climates with customary equipment, and this difficulty is believed to be attributable to excessive water in the air or in the electrodes. A recent research report gives quantitative information on the effects of atmospheric water vapour on welding-arc electrode burn-off rates and electrical characteristics. The tests were made on d.c. arcs in the current range of 20 to 200 A at atmospheric pressure under controlled humidity conditions. The concentrations of atmospheric water vapour in air were in the range of approximately 0·15 to 16% water vapour by volume, a concentration of 0·15% corresponding approximately to the conditions for natural dry weather at 15°F, and a 6·4% concentration to 100% relative humidity at 100°F. The investigations showed that an increase in power consumption is attendant on burn-off rate increases arising from an increase in atmospheric water vapour, assuming other factors to remain the same. It was also found that this increase in power is obtained through an increase in arc voltage. The increases in burn-off rates accompanying increases in atmospheric water vapour appear to be at least partially attributable to increased chemical action in the case of a negative tungsten electrode, but to be mostly attributable to increased rates of energy transfer to the electrodes in the case of copper and iron electrode materials.

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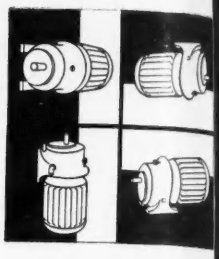

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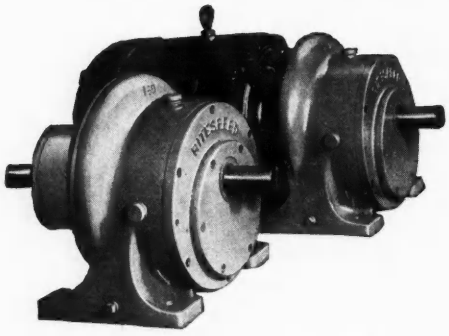

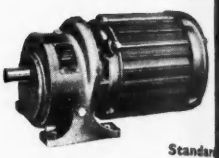

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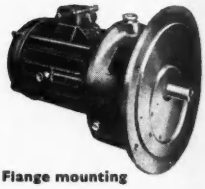

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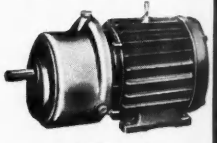

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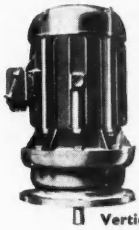

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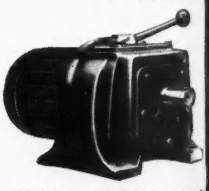

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THE ENGINEERS' DIGEST
REVIEW OF WORLD ENGINEERING PROGRESS
VOL. XVIII No. 6 JUNE, 1957

The 22nd Salon International de l'Aéronautique

To the visitor from Britain, comparison between the 22nd Paris Air Show and the S.B.A.C. Exhibition and Flying Display is only natural, and in recent years the Salon has come much closer to the " Farnborough Show " both in form and organization. It is true, however, that its location at Le Bourget obliges the flying display, as distinct from the S.B.A.C. display, to be held in a crowded, controlled air space.

The main difference between the French and British shows is the fact that, as its name implies, the Salon is a truly international event. As such, it is of special interest to British visitors. Another interesting point is the prominence given to private aircraft. Thus, it was possible to compare a four-seater Piper Cub at about £3500 with an executive-type Piper twin-engine luxury model in the £20,000 class. Similarly, several small aircraft for private flying, of French, British, German, Italian, Czech, and Polish origin, were displayed, together with a number of French gliders and two versions of the two-seater " Djin " helicopter. Of these, a new French all-wood monoplane, a conventional but beautifully finished small Italian four-seater, and a highly aerobatic Czech single-engine two-seater were particularly interesting.

There can be no doubt that private, and especially club, aviation receives much greater official support in France and in some other Continental countries than it does in England, and this support is spreading. As a result, such thoroughly practical points as cost, utility, ease of maintenance, and flying qualities assume much greater importance than features of merely novel technical interest. In this context, three points of special interest are (1) the diverse efforts made to achieve short take-off and landing runs ; (2) the renewed interest in pusher-type aircraft ; and (3) aircraft with high aspect ratios. Insofar as short take-off and landing runs are concerned, a Spanish-built Dornier machine, with a leading-edge slot and a large slotted flap, seemed to have the neatest appearance. With regard to pusher-type aircraft, one German-built machine incorporated a fin behind the propeller—a feature which clearly needed some courage to be presented as the type capable of the greatest diversity among all light aircraft.

In a more ambitious category, mention must be made for novelty and interest of an Italian amphibian single-engine four-seater with a raised pusher power-unit, the Air-Fouga twin-jet " Magister " trainer, capable of a top speed of over 450 mph with two Turbomeca " Marboré " turbo-jet engines, and finally the Hurel-Dubois-Miles high aspect ratio small cargo aircraft with two pusher propellers, built in association with Miles Aircraft, and in fact a converted " Aerovan ".

However, whilst there was a wide variety to choose from in the airframe field, the same cannot be said for new exhibits in the field of light engines. Even the unique Turbomeca range of engines featured no smaller units, major attention being apparently devoted to the production of larger engines. In fact, below 100 hp, only one engine, old or new, was exhibited, this being the Agusta Giovanni 4-cylinder, opposed, 72-hp engine, in two versions, i.e., horizontal and vertical, weighing 148 lb and said to be now in production.

In the international aircraft class, the current Salon reveals some remarkable achievements of the British, French, Swedish, and American aircraft industries. To the non-specialist, only a few highlights, not already commonplaces in the world technical press, are of interest, although it is in this range that the show is most impressive to the specialist and bears evidence of the great technical work which lies behind these achievements.

Internationally, jet bombers grow larger and faster ; more and more turbo-jet fighters pierce the sound barrier ; bigger, faster, and better guided missiles are being developed ; trainers are jet-propelled ; turbo-jet engines are larger, and thrust augmentation by reheat is more widespread ; mixed-power fighters, using turbo-jets and rockets, are being produced ; and rocket engines are becoming more numerous and more powerful. Most of these developments are dominated by the U.S.A., but the French have their share, for which they must be greatly indebted to the Marcel Dassault Company and its family of fighters. The " Mystère " series is now completed by the introduction of the " Super-Mystère B-2 ", already in batch production ; in fact, these are the first European supersonic fighter aircraft to have reached production status. These more or less conventional machines, powered by SNECMA " Atar " turbo-jet engines with reheat, attaining a thrust of 9250 lb, have been followed by the " Mirage " delta-wing fighters, of which the second prototype is nearly ready to fly, the (still secret) performance being estimated to be certainly higher than 1·7 Mach in horizontal flight. On the other hand, the " Super-Mystère " design finds its successors in a range of " Etendard " tactical-support fighters with versions incorporating different French and British turbo-jet engines.

France also demonstrated a number of more futuristic types in the field of military aviation, one of these being the Sud-Aviation mixed-power " Trident " fighter, with two Armstrong Siddeley " Viper " turbo-jet engines and a group of S.E.P.R. (Société d'Étude de la Propulsion par Réaction) rocket engines with a total thrust of 3300 lb. An altogether original development, though by no means new in concept, was the ram-jet fighter built by the Société René Leduc et Fils, this being the first aircraft of its type anywhere in the world to have actually lifted a pilot from the ground without the aid of any other form of propulsion. Even more futuristic, though certainly not unique, is the SNECMA "flying stovepipe", which is, in fact, an "Atar" turbo-jet unit standing on its tail, with a pilot sitting on top and controlling the machine by means of a number of auxiliary jets. Compared with the Rolls-Royce " flying bedstead ", this arrangement seems to incorporate more engine and less bedstead. Thrust

augmentation by means of an annular wing ejector (the " Coleopter " principle) is said to be under development.

The 22nd Salon already bears evidence of the intense activity devoted to guided missiles. Of these, two models were exhibited by the U.S. Air Force, one of the ground-to-air type, and the other of the ground-to-ground type and capable of carrying an atomic warhead. French developments include virtually the whole gamut of missiles, but it is safe to assume that the information revealed for public consumption is hardly likely to give a very illuminating impression.

Those typically French developments, the high-aspect-ratio wing of Hurel-Dubois and the Turbomeca range of small gas turbines, have now invaded the larger brackets. Thus, the H.D.321, with two Wright Cyclone engines, has a span of 148 ft and is designed to carry 44 passengers at a cruising speed of 172 mph. Take-off and landing runs are very short, without the usual penalty of reduced speed. Of the new Turbomeca engines, three are turbo-jet units of 550, 1450, and 2420 lb thrust respectively, the 2420-lb model, designated " Gabizo ", weighing 560 lb and having an overall diameter of about 26 in. It is interesting to note that, in the entire Turbomeca range of turbo-jet units, an almost constant specific fuel consumption of just over 1 lb per lb thrust at maximum power is obtained, consumption remaining nearly the same, or even somewhat improved, at the highest continuous rating, i.e., 80% of maximum power. Another new Turbomeca unit, the " Autan II ", is a gas generator with a pressure ratio of 5 : 1, giving a maximum mass flow of 3 lb/sec.

With regard to American engines for helicopters, Aircooled Motors Inc. now announce that their vertical-shaft, 210-hp Franklin engine is now available in a turbo-charged version which will maintain its power rating up to an altitude of 12,000 ft at the expense of an added engine weight of 40 lb. In addition to its already well-known powerful turbo-jet engine destined for the medium-range Convair 880 airliner, the General Electric Co. also showed their T.58 shaft turbine for helicopters. This is an altogether revolutionary unit, with its promise of 1020 hp for an engine weight of only 324 lb and its specific fuel consumption of 0·67 lb/hp-hr. In contrast with the Turbomeca shaft turbine, the T.58 is a gas generator with a free turbine, an arrangement which has special advantages for matching the optimum speed of the helicopter rotor, although the control characteristics are still subject to controversy. There can be no doubt that, in view of its very low weight, compared with engines which even now are only in an advanced stage of development, its further proving trials will be awaited with the keenest interest.

The major international air lines are now exposed to the full blast of salesmanship surrounding the American Douglas and Boeing turbo-jet airliner ventures. Those less prone to participate in the craze for speed and more speed may wonder at what point increased speeds are no longer economically practicable. However that may be, France has also entered the race for world-class jet airliners with the " Caravelle ", built by Sud Aviation. This aircraft, powered by two Rolls-Royce " Avon " engines of 10,500 lb thrust, resembles the " Comet " in appearance, but has the distinctive feature of engines mounted near the tail on both sides of the fuselage. With 70 passengers over a stage length of about 1600 miles, a cruising speed of about 475 mph is envisaged. The first machines are expected to be delivered to Air France in 1958.

It is in the medium-size helicopter that the French aircraft industry has a machine to offer without parallel anywhere. The Sud Aviation " Alouette II " is the first shaft-driven gas-turbine helicopter in production. It is powered by the Turbomeca " Artouste " turbine, which delivers a maximum of 400 hp. With its useful load of about 1265 lb (compared with its all-up weight of 2970 lb), and its cruising speed of about 106 mph, this helicopter, at least in its basic version without styling or streamlining, puts the helicopter in a new class of structural efficiency, unsurpassed even by the best fixed-wing aircraft. It is also the first helicopter with a conventional three-bladed fully articulated rotor to operate with a skid undercarriage. Several versions of the " Alouette II " were shown, including an elegantly styled executive model.

Among other helicopters, the pressure-jet-driven two-seater " Djin " was strongly in evidence, and featured a variety of equipment, including a version with spraying booms.

The only remarkable feature of a Polish helicopter on exhibition was the provision of de-icing equipment for both the main and tail rotors. This helicopter, which resembles the Sikorsky-Westland five-seater type, is said to be built under Russian licence, and certainly the presence of a number of Russian inscriptions on some instruments and of a few Russian inspectors' stamps gives credence to this supposition.

In common with all aeronautical exhibitions, most exhibitors are concerned with equipment and components. It is in this field that the small firm often has as good a chance as its large competitor of producing something really outstanding. In this survey, no attempt can be made to summarize all the exhibits, but a few have been singled out for special interest or novelty.

Among typical aircraft units, the Curtiss-Wright Propeller Division exhibited a variable exhaust-nozzle control for turbo-jet engines. This is an all-mechanical control system adaptable to several drive methods, such as an accessory gearbox, compressor-bled air, etc. A mechanical computer can be adjusted to govern any combination of turbine speed, temperature, and pressure, and the same type of control unit can actuate not only a variable exhaust nozzle but also a thrust reverser, which consists of two bent channel sections, normally positioned outside the nozzle but brought together in front of it for thrust reversal. The fact that high temperatures are involved has been responsible for the development of an all-mechanical unit, but it is certainly of great interest that what appears to be a light, efficient, extremely powerful (up to 25,000-lb thrust), and very versatile unit for reliable service has been designed and constructed without the use of pneumatic, hydraulic, electrical, or electronic means.

Another Curtiss-Wright all-mechanical control unit, the development of which was not dictated by high temperatures, is their engine-speed control for helicopters, this being essentially a speed governor which automatically controls the engine throttle, with the conventional pilot's twist-grip setting the speed of the governor, instead of controlling the throttle directly. The unit comprises a centrifugal speed element, a variable-speed gear acting as a power-amplifying integrator, and another variable-speed gear which acts as a servo-motor, the total effect being that of a proportional (speed-error) cum integrating (phase-error) control device.

Of more general application is the self-contained hydraulic jack exhibited by Hispano Suiza. In this

design, which appears to be of practical importance, the jack incorporates a pump driven by an electric motor. Thus, merely at the cost of extending the electrical distribution system, all the advantages of hydraulic power are obtained, without the embarrassment of pipelines.

Among other aircraft accessories, Bronzavia exhibited an original, but not unique, turbo-generator driven by compressor-bled air and capable of supplying 20 kVA, 400 cps a.c. The unit weighs approximately 85 lb, and at ground level has an air consumption of about 65 lb/min at a pressure ratio of 2, or 30 lb/min at a pressure ratio of 5.

Another air-driven unit was exhibited by the Société Air-Équipement and comprises a winch carried for rescue work on the "Alouette II" helicopter. This winch, which has a maximum pull of about 440 lb and can accommodate over 80 ft of cable, weighs only 25 lb and contains a positive-displacement pneumatic motor operating in both directions of rotation. The unit is remote-controlled from the pilot's stick and incorporates automatic limit-stops and a remote-controlled explosive-type emergency cut-off device.

Another interesting exhibit from the Société Air-Équipement was their miniaturized radio-compass, model RCB-2. Measuring only about $4\frac{1}{2} \times 5\frac{3}{8} \times 6\frac{1}{2}$ in. and weighing less than 11 lb, this extremely compact unit covers a range between 200 and 800 kcs, utilizes 27 V d.c., and, with an electromagnetic field of less than 30 μV per metre, has a deviation of less than ± 2 deg.

Other miniaturized flying control equipment was exhibited by the Société Française d'Équipement pour la Navigation Aérienne. Separate automatic-pilot control units are provided for each axis, for a weight of about 27 lb per axis, while a servo-mechanical yawing damper, to suppress high-frequency yaw oscillations, is available for a weight penalty of only $10\frac{1}{2}$ lb.

Whilst some of the above units and many others in communication and intercommunication equipment are miniaturized by the use of transistors, great efforts to achieve reduction in size and weight by ingenious and refined mechanical design were evident on many stands. Noteworthy among these are the transmitter units shown by Établissements Faure Herman for electronically controlled fuel-supply systems. This type of unit converts the rotation of a tiny turbine into electrical impulses emanating from a coil with a magnetic core mounted outside the transmitter body. One of the four turbine blades carries a small magnet, whose passage under the coil creates the impulse, and electronic relays in a dividing circuit transmit one amplified signal in sixteen received, the amplified signals being converted into direct current with a voltage proportional to their frequency. A transmitter unit of this type, capable of measuring between 270 and 4000 gallons per hour, weighs just over 1 lb and occupies a space of 3 in. in diameter by $5\frac{1}{8}$ in. in length.

A quite remarkable step forward in the problem of reducing the size of electrical multi-wire connectors, especially for aircraft, has been made by the Société Générale d'Équipements. Made in several types and sizes mainly from stainless-steel stampings, these new connectors are about 30% lighter than existing standard connectors. Thus, for instance, the 19-pin connector has an overall diameter of about $1\frac{5}{16}$ in. and, in its standard cable-connecting version, weighs about $2\frac{1}{2}$ oz, including the plug and socket assemblies.

A 12-kW, 30-V continuously rated d.c. aircraft generator, with the outstandingly low weight of 57 lb, was exhibited by Labinal. Measuring about $6\frac{3}{4}$ in. in diameter by $15\frac{1}{2}$ in. in length, this compact unit has a safe speed range of from 3600 to 8000 rpm and is fitted with a torsional-vibration damper.

In the purely mechanical field, the range of ball and roller bearings exhibited by Les Applications du Roulement for aircraft, light-engineering, and instrument applications was especially noteworthy. Of particular interest is their greatly increased range of sealed bearings, which include most types of double-row, self-aligning, and deep-groove ball bearings and barrel roller bearings. In addition to a number of special types, other interesting items in this field included flanged bearings, with a flange integral with the spherical ring carrying the outer race; bearings with a sleeve extension integral with the inner race; bearings with circlip grooves; bearings with full-life oil seals and labyrinth seals; and bearings of small cross-section for standard diameters.

Exhibits by S.A.A.B., of Sweden, included demonstrations by means of models of their "Fluid-Form" method of forming sheet blanks into complicated shapes. This method requires only one die block, while the mating die punch is replaced by standard components of the S.A.A.B. "Fluid-Form" unit, the punch half of the complete die being replaced by a flexible diaphragm which acts both as a die-holder and a punch face. The flexible diaphragm is the lower seal of a pressure chamber and, when the pressure chamber is lowered onto the die block, the blank is held. Further advance of the ram pushes the cylindrical punch into the pressure chamber, which is filled with a liquid, and, as a result of the pressure, the diaphragm deforms and presses the blank into the die block. The punch is then raised and eventually lifts the pressure chamber, after which the blank is pneumatically ejected from the die. For this purpose, the die block is often made in two halves, usually of a plastic material or of cast iron.

A new rubber die press process, mainly for aluminium-alloy sheet-metal components, has also been announced recently by S.A.A.B., the idea being to eliminate spring-back and distortion. The process consists of dividing pressing into two operations. In the first, an approximately correct flange angle and a pre-arranged distortion of the bending curve are imposed; in the second, the flanges are pressed against vertical tool faces, so that the outer flange is stretched and the inner flange compressed. In this way it is possible to arrange for the deformations and stresses arising from the first and second pressing operations to counteract each other or even to be adjusted to cancel each other almost completely, so that spring-back is eliminated and no hand-finishing is required.

In this survey, British contributions to the Salon have deliberately been omitted, as it is felt that these have been adequately covered in the British aeronautical press. At the same time, however, it must be said that, though France has now shown herself only too clearly to be a leader in several branches of aeronautics, neither in military nor in civil aviation is there anything which can be said to diminish the status of British contributions to world aviation, nor, for that matter, anything to suggest a need for revision of the main lines of British thinking on major aviation doctrines. Nevertheless, it must be said that, in the particular branch of aviation concerned with small aircraft of any type and with private flying, Britain's contribution is sadly below her resources and unworthy of the enthusiasm of her people, who, after all, have always been one of the most air-minded in the world.

CANADA

Plastic Design Methods for Steel Structures

By B. THURLIMANN. (From *The Engineering Journal*, Vol. 40, No. 2, February 1957, pp. 126–128.)

Experimental evidence shows that plastic methods can predict the ultimate load of a steel frame with a degree of accuracy on which design can be safely based. In this paper, the basic principles of the concept of plastic design are discussed in relation to present elastic methods, and indications are given of theoretical implications and practical developments.

ELASTIC design methods are nowadays completely governed by the concept of allowable stress. It should, however, be borne in mind that the purpose of design is not to keep all stresses in a structure below, say, 20,000 psi, but to produce a structure which will fulfil its intended use satisfactorily. Elastic design is admittedly one successful approach to the problem ; however, this fact does not imply that it is the only approach possible or that its application leads to the most economical use of materials.

In the calculation of elastic stress, the stresses in a complicated structure are determined under all imaginable loading conditions. These nominally computed stresses are supposed never to exceed the prescribed allowable design stresses. However, in actual performance under full design loads, some parts will be greatly understressed compared with this analysis, while others will be overstressed, even to the point where actual yielding occurs. There is ample experimental evidence of the considerable difference between nominally computed stresses and actually induced stresses, the reason being that, in the stress computations, the presence of residual stresses is not taken into account. Rolled beams, for instance, have locked-in cooling residual stresses of from 10,000 to 15,000 psi. Welding produces stresses as high as the yield-point value of the material. Furthermore, fabrication operations, such as cold bending, cambering, punching of holes, etc., induce additional stresses not accounted for in the analysis. In addition, during erection, stresses are produced by forcing members into place, the actual sequence of erection causing a different stress distribution than that given by the analysis based on the dead load applied to the completed structure. Assumed simplifications in the analysis constitute another source of variance between calculated stresses and those actually present. For instance, framed structures under lateral loads are commonly analysed by using either the so-called " portal " or " cantilever " method. Applying both methods to the same problem leads to quite different results, and it can easily be shown that the actual stresses do not follow either method.

With regard to the design of connections (either bolted, riveted, or welded), it may appear, at first glance, that this is also based on prescribed stresses which should never be exceeded. Examining the problem more closely, however, will show immediately that parts of the connections will be above, and other parts below, these prescribed values. For instance, the end rivets in a row of four to five rivets carry a load considerably above the computed nominal load.

An important point to remember is that steel is able to deform plastically and will therefore relieve overstressed parts and bring into play understressed parts. Without this property of ductility, the present practice of neglecting residual stresses and of using simplified design procedures could not be justified. Plastic design methods are essentially a conscious acceptance of subconsciously implied justifications of elastic design. The ability of steel to deform plastically is clearly recognized. By forming so-called " plastic hinges " the individual members will develop their full plastic moment value, and the structure is able to redistribute its moments. Design is no longer based on an allowable stress concept but on the maximum load-carrying capacity of the structure as such. By limiting the working loads to a chosen percentage of this ultimate load, a safe structure is obtained. It should be mentioned that checks on deflections, stability, etc. are sometimes necessary, as in present-day elastic design, to ensure the proper performance of the structure. However, the essential design criterion for plastic design is the load-carrying capacity of the structure.

At present, methods of plastic analysis are fairly well developed for framed structures, all these methods assuming that failure will occur owing to formation of sufficient plastic hinges to transform the structure into a mechanism. To ensure such a type of failure, precautions must be taken to avoid failure by instability.

In the author's opinion, the biggest progress in structural engineering is likely to be made by a re-examination of the concept of safety. In this connection, a structure should fulfil its intended use without the possibility of collapse or excessive deformations. Factors influencing safety are possible variations in the properties of the materials used, variations in dimensions, the quality and control of workmanship, corrosion, simplifications in design assumptions, overloads, etc. At present, a constant factor of $33/20 = 1{\cdot}65$ against nominal yielding is used indiscriminately for all types of structures. This does not seem justified, as it would seem quite unreasonable, for instance, to design a water tank with the same safety factor as a warehouse.

Plastic design permits a much more realistic approach to this problem, as it provides methods of computing the actual load-carrying capacities of structures. Elastic methods, on the other hand, are unable to predict the ultimate load of statically indeterminate structures, but can merely specify a nominal load at which first yielding will occur. It would seem that considerable progress will eventually be made in this field, leading to a clarification of the basic issues and to a more realistic approach to the problem of safety. Certainly, the acceptance of the ultimate load-carrying capacity as a new basis for design and, with it, the introduction of plastic analysis, will bring about changes in the conception, the design and the fabrication of steel structures.

With regard to practical developments, a strong tendency should develop towards statically indeterminate structures, one reason being that plastic methods of analysis are much easier and shorter in such cases than corresponding elastic methods. There should be little excuse for avoiding indeterminacy on the basis of too cumbersome an analysis. Even in cases of possible foundation settlements, indeterminate systems can be used, for plastic analysis shows that such movements, kept within reasonable limits, do not influence the carrying capacity. Continuity and the constant safety factor against ultimate load introduced through plastic analysis will greatly reduce the total tonnage of steel.

Rolled sections will be used primarily as members. There should be less need for the built-up sections with variable moment of inertia, the haunched knees, and the

cover-plates, often used in elastic design to reduce peak stresses. Plastic design recognizes the fact that, through formation of yield hinges, the structure redistributes its forces, relieving overstressed parts and loading understressed portions. For large structures offering difficult conditions for lateral supports, e.g., sports arenas and aircraft hangars, built-up box sections may offer a neat and economic solution. Such sections require little lateral support, owing to their great torsional stiffness. To provide the required continuity of the connections, welding is necessary, at least for shop work. At present, welding is too often used as a simple substitute for riveting, without giving careful consideration to details. Continuous corner connections, and interior two- and four-way connections will present a new challenge. Much will depend on the successful solutions of such details to turn the saving in overall weight into a saving in costs. Shop welding should be used to the widest extent possible in building up large sub-assemblies. For instance, an interior four-way connection can be made by welding four beam stubs to the column. In erection, the beam splices, placed at locations of low moment, offer considerably less difficulty than a fully continuous beam-column splice. High-tensile bolts may offer a very economical solution for field splicing. Even to-day, high-tensile bolts compete successfully with riveting and welding in field work. In some instances, simpler details may be obtained by changing from the usual practice of shear connections (friction between the clamped plates) to direct tension-compression connections, with the bolts in the direction of the forces.

In fabrication, proper care must be taken to conserve the ductility of the material. Punching of holes must be avoided in the tension zones of potential plastic hinges. In the neighbourhood of such holes the material is very brittle, owing to plastic deformations caused by the punching operation. Relatively small strains are sufficient to cause brittle fracture. The same reasons exclude shearing of plates, cold bending of parts, and other operations leading to the embrittlement of the material. Small plastic deformations, however, caused by straightening or cambering of members can be tolerated, as the material will not lose its ductility. In addition, stress raisers should be eliminated, and special attention must be given to complicated welding details, in order to avoid states of triaxial tension.

U.S.A.

Designing Electronic Equipment To Resist Nuclear Radiation

By H. L. MORGAN. (From *Electronics*, Vol. 30, No. 5, May 1, 1957, pp. 155–157, 2 illustrations.)

NUCLEAR power for aircraft and ships requires electronic equipment capable of operation in areas of high nuclear radiation. The components of nuclear radiation of concern to designers are fast neutrons, slow and thermal neutrons, and gamma rays. The radiation rates of each is a function of the power being generated, shielding, and distance between the reactor and the equipment.

Each type of nuclear radiation affects materials differently. Slow neutrons are captured by atoms in activation reactions. This induced artificial radioactivity will generally produce secondary gamma rays, as with cadmium. Boron absorbs slow neutrons and emits alpha particles. Of the two, the alpha particles are more desirable, since they are easily stopped. The amount of artificial radioactivity induced by slow neutrons is a function of the cross-section for capture possessed by the material. Some metals, notably cadmium, cobalt, and manganese, have very large cross-sections for slow neutrons.

Secondary radiation adds to the general radiation problem and makes difficult the servicing of equipment once exposed to nuclear radiation.

Shielding against slow neutrons is a simple and inexpensive procedure. A quarter-inch shield of boron carbide/aluminium alloy will attenuate the slow neutron flux by a factor of 10^5.

Fast neutrons do not have the large cross-section for capture possessed by slow neutrons, but they have a large kinetic energy. A nuclear reactor will produce neutrons with energies up to 15 MeV, but the bulk of those to be contended with are around 1 or 2 MeV.

Gamma rays have far smaller cross-sections for reaction than fast neutrons, and thus cause little radioactivation. Ionization of gas by gamma rays is less than for an equal number of fast neutrons possessing the same energy. Except for ionization and reactions with electrons, gamma rays are not particularly damaging to electronic equipment in quantities of the order of 10^{15} per cm^2. Appreciable damage may begin to show at 10^{18} gamma rays per cm^2.

Design factors to be contended with by the engineer are radioactivation, ionization, and structural damage. Radioactivation will restrict the serviceability of any equipment. Two techniques are possible :—(1) Materials with large cross-sections for capture of slow neutrons with gamma secondaries should be avoided or reduced to a minimum, and (2) materials with short half-lives should be used for the structure. An example of the first consideration is the use of nickel or tin in place of cadmium plating. As an example of the second consideration, aluminium has a very short half-life (2·4 minutes) whereas iron has a 2·06 year half-life. Iron activation would build up throughout the life of the equipment, but aluminium activation would be reduced to 0·017% of peak value in 30 minutes.

Figure 1a illustrates the build-up of induced radioactivity during an operating period of 40 hours. Less than 1% of the total activation of aluminium would remain at the end of the irradiation period. On the other hand, the secondary radiation rate at shut-down would be much higher for aluminium than for iron, as is shown in Fig. 1b. Fig. 1c compares the half-life parameter on a basis of radiation rate and time after shut-down.

Both aluminium and iron are almost invariably used in the form of alloys. In considering an alloy for use in a nuclear radiation environment, the properties of all components must be evaluated. Cobalt is generally a component of aluminium-alloy magnets and has a large secondary radiation. If the equipment is to be serviced, then cobalt-containing materials should be shielded with boron alloy.

Ionization is not generally a problem in metals or in ionic-bond materials. However, in gases or in insulators

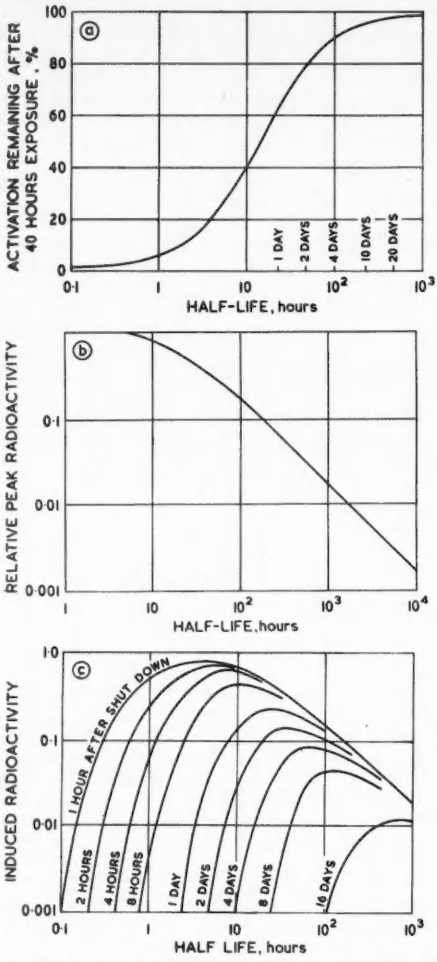


Fig. 1. Graphs showing (a) residual activation, (b) radioactivity at shutdown, and (c) relative radiation of materials as functions of half-life.

it can be a severe problem. In waveguides, ionization will reduce the maximum power that can be maintained without breakdown. This can be solved by pressurization.

Gaseous tubes, whose operation depends on ionization, are not particularly affected by the presence of nuclear radiation. However, gas-amplification phototubes are severely affected. Thyratrons require a grid-cathode ionization intensity several orders of magnitude greater than that likely to be caused by the probable radiation, to safeguard against the risk from false-firing.

High-voltage supplies and pulse modulators require additional insulation, owing to the presence of ionization. Where air pressure can be used, this is as effective as in waveguides. Where pressurization is impractical, immersion in silicone oil or encapsulation in plastics might be considered. The leakage resistance of plastics and other insulators will be reduced by a factor dependent on the radiation rate ; this factor may be as high as 10^3. The battery effect is also due to ionization. A conductor insulated from earth will acquire an appreciable potential with respect to earth, owing to unidirectional travel of ionizing radiation. However, the current is very small and constant, so that the potential developed drops rapidly with decreasing resistance to earth.

Probably the most serious effect of fast neutrons is on semiconductor devices. Data available in the form of test results are somewhat contradictory, but apparently failure may be expected in the interval of 10^{13} to 10^{16} fast neutrons per cm^2. Germanium diodes tend to fail by becoming ohmic, while silicon diodes increase in resistance in both directions.

Some tests indicate that silicon diodes last longer under irradiation than germanium diodes, while other tests indicate the opposite. Only limited data are available on transistor tests. It is likely that transistors are more susceptible to irradiation than are diodes.

Shielding against fast neutrons is mainly a matter of moderating (slowing down by collision) and capture at the thermal energy level. Neutrons lose energy in the largest increments when colliding with objects of equal mass, so that the best moderators are materials containing large quantities of hydrogen.

Water is used as a moderator, but 24 cm of H_2O is required for a 10-to-1 attenuation of fast neutrons. Certain plastics are more effective, but the best, according to data available, is polyethylene, which requires 15·6 cm.

A material known as tetra-methyl-ammonium-borohydride will attenuate fast neutrons by 10-to-1 in 3·5 inches, the boron soaking up the thermalized neutrons. Its density is listed as 0·813 and it is reported to be stable up to 300°F.

If fast-neutron shielding is used, it probably will be employed only for semiconductor devices.

In general, little or no change in physical or electrical properties of plastic materials has been observed up to 10^{15} neutrons per cm^2 ; this, however, appears to be a threshold point.

The effect of radiation on plastics and other insulators mainly appears in capacitors and inductors. Paper, which is a complex organic material with low radiation resistance, must be replaced by materials such as mica, glass, ceramics, mylar, and silicone materials, depending on the application. The magnetic properties of metals and ferrites appear to be unaffected by radiation dosages far beyond anything contemplated here.

Components are available which can operate at high temperatures and for extended periods in a radiation environment. Glass capacitors and fused-oxide resistors appear to be very good. Monolithic ceramic capacitors are in the same class. Some mica capacitors have operated with little modification of properties through extended periods of irradiation, but others have failed, owing to structural failure of the encapsulating plastic.

Metals are very little affected by nuclear radiation in their physical or electrical properties at the radiation flux levels dealt with here. Wire-wound resistors, however, may fail because of insulation failure. A continuous, flexible ceramic coating, if possible, would be highly desirable. Metal film, or other film-type resistors, appear to have good radiation-resistant properties.

Inductors wound from foil (preferably aluminium) appear advantageous for several reasons, i.e., the space factor is better and heat conduction is considerably improved. If aluminium, with its natural oxide and auxiliary insulation, such as mylar, is used, the maximum mylar temperature will be reduced for a given surface temperature. Life, and hence reliability, will be increased. Electromechanical devices such as relays, motors, and selsyns fall into the same class as inductors.

Torsional-Vibration Analysis of 60-deg. Vee Six-Cylinder Engines

By M. Bencini. (From *Rivista di Ingegneria*, Vol. 7, Nos. 3 and 4, March and April, 1957, pp. 245–260 and 401–417, 39 illustrations.)

In the development of the "Flaminia" motor-car, the Lancia Co. of Turin have made a detailed investigation of two versions of a 60 deg.-Vee six-cylinder petrol engine. The two versions considered were basically similar, the main difference being in the crankshaft dimensions. Both engines were designed for normal running speeds up to 5300 rpm. It was decided to carry out the following investigations:—

(1) Calculation of crankshaft stiffness, moments of inertia, natural frequency of vibration, and estimated stresses for various firing orders, with and without various types of vibration dampers.

(2) Measurements of vibration frequency and vibration amplitude, with and without dampers.

The engine data are as follows: Bore and stroke 80 × 81·5 mm, total swept volume 2·458 litres, compression ratio 7·85:1. Maximum power rating 98 hp (metric) at 4800–5000 rpm, with a bmep of 7·48–7·17 kg/cm² and a mean piston speed of 13–13·5 m/sec. Maximum torque 179 newtons-metre (18·1 kgm) at 3000–3300 rpm, with a bmep of 9·22 kg/cm². Maximum continuous speed 5300 rpm, at a mean piston speed of 13·8 m/sec.

Firing orders: For engine I: 1–6–3–2–5–4, 1–6–2–4–3–5, and 1–4–3–6–5–2. For engine II: 1–4–3–6–5–2.*

The crankshafts, flywheels, connecting rods, and pistons, of the two engines had the following values:

	Engine I	Engine II
Number of main bearings	4	4
Journal diameter	60 mm	65 mm
Crankpin diameter	48 mm	52 mm
Mass of crankshaft	20·97 kg	22·87 kg
Crankshaft inertia (balance weights integral with crankwebs)	0·0506 kgm²	0·0552 kgm²
Mass of piston and small end of connecting rod	0·564 kg	0·645 kg
Mass of big end and connecting rod	0·442 kg	0·490 kg
Inertia of reciprocating parts	0·000468 kgm²	0·000535 kgm²
Inertia of rotating part of rod	0·000734 kgm²	0·000814 kgm²
Mass of flywheel	11·33 kg	11·33 kg
Inertia of flywheel	0·1498 kgm²	0·1498 kgm²

Natural-Frequency Calculations

The moments of inertia of the crankshafts were determined experimentally, using a bifilar pendulum suspension, i.e., each crankshaft was provided with two piano wires of 0·5 mm diameter fixed at diametrically opposite positions on its end flange, the crankshaft being suspended vertically. Stop-watch readings of the time taken for 20, 30, 100, 150, and 200 vibrations gave vibration periods accurate to within 0·02 sec. The polar mass moment of inertia was then evaluated from the formula

$$J = \left(\frac{\tau}{2\pi}\right)^2 WR^2/(4L) \qquad [\text{kgm}^2]$$

where τ = period of one vibration [sec], W = weight of the component [newtons], R = radial distance [m] from centre of shaft or flywheel to piano wire, and L = length of piano wire [m]. It was found that the measured values of crankshaft inertia were about 1 to 1·5% higher than the calculated values; this is understandable, in view of the approximation methods used for calculating the moments of inertia of crankwebs, etc.

The inertias of connecting rods and pistons were calculated in the usual manner, taking one half of the inertias of the reciprocating parts as their average value.

The torsional stiffness of the crankshafts was determined by static measurements and by calculations. It was found that the measured values were 50% lower than those obtained by calculations. This indicates that the usual crankshaft formulae are only rough approximations.

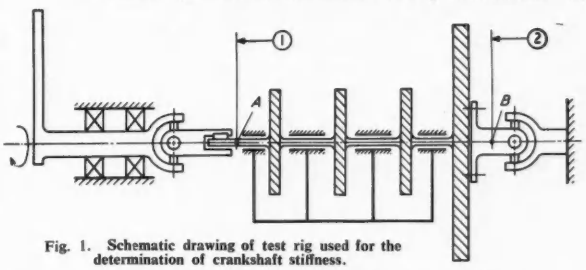


Fig. 1. Schematic drawing of test rig used for the determination of crankshaft stiffness.

For static stiffness measurements, the crankshaft was mounted in its crankcase (see Fig. 1), the flywheel being connected to a rigid end-bracket by means of a universal joint. The front end of the crankshaft was subjected to pure torque by means of a lever via another universal joint. The shaft twist under the torque was measured by means of two steel indicators fixed at positions *A* and *B*, in Fig. 1; the indicators were used to determine and mark off the distances $AC = BC = 10{\cdot}32$ cm in the horizontal plane through the shaft axis. At this distance, a rotation of 20 angular seconds corresponded to a vertical reading of 0·01 mm. The twist under load was determined by optical comparators, the instrument at position (1) reading 0·01 mm per division, while a more sensitive instrument, giving a reading of 0·001 mm per division, was arranged at (2), where there was much less torsional deflection. The procedure for these tests was as follows: First, a preload torque of 16·7 kgm was applied, to take up play in the universal joints and the main bearings; then, various additional torques, up to 75 kgm, were superimposed. For both shafts the total twist was measured and found to be within the range of 0·25–0·30 deg.

Tests were also made of the crankshafts with the crankcase removed, in order to determine the effect of bearing constraint. It was found that the stiffness of the crankshafts without bearings, etc. was only 0·7–0·8 of that obtained with the bearings fitted. The principal values [newton-metres/rad] are as follows:

Crankshaft	Engine I	Engine II
Calculated stiffness, by Carter's formula	$22{\cdot}5\times10^4$	$30{\cdot}7\times10^4$
Measured stiffness in bearings	$8{\cdot}08\times10^4$	$10{\cdot}2\times10^4$
Measured stiffness without bearings	$6{\cdot}37\times10^4$	$7{\cdot}58\times10^4$

(1 Nm/rad = 0·102 kgm/rad)

The one-node natural frequency of the engine-and-flywheel system was then calculated by means of Holzer

* The "A" bank consists of cylinders 1, 3, and 5, while the "B" bank consists of cylinders 2, 4, and 6, both numbered from the free end of the crankshaft.

tables and by the Lewis formula. The six-cylinder Vee engine crankshaft was reduced for the Holzer-table evaluation to a system of three concentrated masses for the cylinder inertias (taken in pairs) with their adjacent portions of the crankshaft, and a fourth concentrated mass for the flywheel, as shown in Fig. 2.

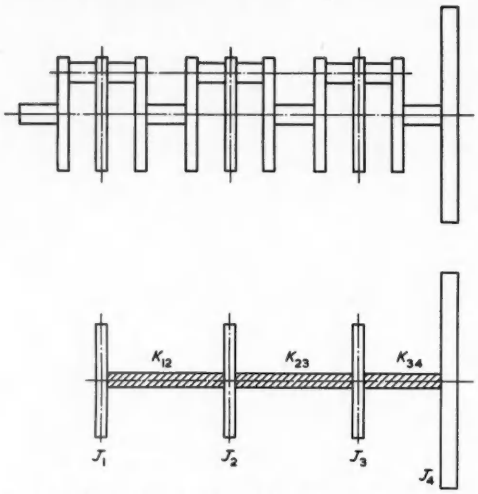


Fig. 2. Reduction of a V-6 engine-and-flywheel system to an equivalent 4-mass system.

For the sake of simplicity, all cranks are shown in the same plane.

Although the overall stiffness of the crankshafts was known from the measurements, the question as to the stiffness of the crankthrow portions between each pair of cylinder inertias was still undetermined. It was decided to assign to each section a stiffness equal to that obtained by Carter's formula multiplied by the ratio of measured to calculated overall crankshaft stiffness derived from the values in the above table. Subsequently, a further correction was applied, from the results of tests of a model of a crankthrow of engine I. With these values, the torsional-vibration frequency was calculated and was between 5·3% and 2·1% lower than the measured frequency.

The Holzer tables for the two engine-and-flywheel systems are given below.

Engine I crankshaft. $F = 17{,}720$ vpm $\omega = 1856$ rad/sec

Mass No.	$J \times 10^3$ (1)	$J\omega^2 \times 10^{-3}$ (2)	β (3)	$J\omega^2\beta \times 10^{-3}$ (4)	$\Sigma J\omega^2\beta \times 10^{-3}$ (5)	$K \times 10^{-5}$ (6)	(7)
1	20·23	69·7	1·000	69·7	69·7	2·10	0·332
2	20·23	69·7	0·668	46·5	116·2	2·10	0·553
3	20·23	69·7	0·115	8·0	124·2	3·50	0·355
4	149·8	516·0	–0·240	–123·9	+0·3		

(Note—Column (7) = column (5) divided by column (6).)

Engine II crankshaft. $F = 19{,}630$ vpm $\omega = 2055$ rad/sec

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	21·10	89·05	1·000	89·05	89·05	2·66	0·3348
2	21·10	89·05	0·6652	59·25	148·3	2·66	0·5575
3	21·10	89·05	0·1077	9·60	157·9	4·43	0·3564
4	149·8	632·5	–0·2487	–157·3	+0·6		

For the natural frequency calculations by Lewis's formula, it is assumed that the curve of relative amplitudes from mass No. 1 to the flywheel is a cosine curve,

$$\beta(x) = \beta_1 \cos (kx + \varphi)$$

where $\beta_1 = 1{\cdot}000$, $k = (\omega/L)\sqrt{J_A/K_A}$, and φ = phase angle, with ω = phase velocity, J_A = total value of all cylinder inertias, K_A = overall stiffness of crankshaft, L = length of crankshaft, and x = distance along crankshaft axis.

It may be noted that $kL = \Theta$ is the number of radians over which the cosine curve extends over the length L of the shaft. The torque is

$$T(x) = \omega\beta_1 \sqrt{J_A K_A} \sin (kx + \varphi)$$

At the free end ($x = 0$) of the shaft, $T(0) = 0$, hence $\varphi = 0$. At the driving end ($x = L$), therefore, the torque due to the equivalent distributed shaft inertia acting on the flywheel is $T(L) = \omega\beta_1\sqrt{J_A K_A} \sin \Theta$. For equilibrium, this must be equal and opposite to the torque of the flywheel on the shaft, which is $-J_4\omega^2\beta_4$. The value of ω can then be obtained from this equilibrium equation, and hence the value of Θ and the distance of the node from the flywheel end. The evaluations are as follows :—

Engine I crankshaft : $J_A = 60{\cdot}69 \times 10^{-3}$ kgm²; $K_A = 8{\cdot}08 \times 10^4$ Nm/rad; $\omega = 2070$ rad/sec (trial value) ; $\Theta = 1{\cdot}793$ rad $= 102{\cdot}7°$; $\beta_4 = -0{\cdot}220$ rad ; shaft torque $T(L) = +141{\cdot}5 \times 10^3$ Nm; flywheel torque $T_4 = 149{\cdot}8 \times 10^{-3} \times (2070)^2 \times (-0{\cdot}220) = -141{\cdot}2 \times 10^3$ Nm ; $T(L) + T_4 \cong 0$. Hence $F = 19{,}770$ vpm.

Engine II crankshaft : $J_A = 63{\cdot}3 \times 10^{-3}$ kgm²; $K_A = 10{\cdot}2 \times 10^4$ Nm/rad; $\omega = 2286$ rad/sec (trial value) ; $\Theta = 1{\cdot}801$ rad $= 103{\cdot}2°$; $\beta_4 = -0{\cdot}238$ rad ; shaft torque $T(L) = +178{\cdot}8 \times 10^3$ Nm; flywheel torque $T_4 = -178{\cdot}1 \times 10^3$ Nm. $T(L) + T_4 \cong 0$. Hence $F = 21{,}850$ vpm.

It is of interest to note that the ratio of the natural frequencies obtained by the Holzer tables and the Lewis method is practically the same for both crankshafts, i.e., 19,770/17,720 = 1·115 for the crankshaft of engine I, and 21,850/19,630 = 1·112 for the crankshaft of engine II.

The measured frequencies for these two versions were 18,670 vpm and 20,036 vpm respectively, i.e., between those obtained by the two calculation methods. It may be added that, with an increasing number of masses, both calculations will tend to coincide and should also agree better with the measured value. The Lewis method involves less calculation than the Holzer method for natural frequencies ; it gives, in fact, a better representation of distributed-inertia torques for multi-cylinder in-line engines with equal crankthrow stiffnesses and equal moments of inertia per line.

Predicted Values of Vibration Amplitudes

A " critical speed " N_c is an engine speed which is an integer sub-multiple of the vibration frequency for two-stroke engines ; for four-stroke engines, the " order number " of this critical speed can be a whole number or a half-order number ; in both cases the order number is obtained as $F/N_c = m$ [vibrations per revolution].

The severity of the critical, i.e., the amplitude of vibration at the resonant speed, depends on the value of the gas-torque and inertia-torque harmonics of the order considered, and also on their combined effect due to the various cylinders. This effect is determined by the firing order and the crank-angle arrangement used to determine the " phase vector sum " of each particular order.

If $T_m = m$th order vibratory torque due to each engine cylinder (obtained as the product of piston area, crank radius, and mth order gas pressure harmonic), the total work performed by the mth order torque from all the cylinders, during one vibration cycle, will be

$$U_m = \pi T_m \Sigma(\beta_i \sin\psi_i),$$

where $\Sigma\beta_i\sin\psi_i$ = vector sum of vibration amplitudes at the engine masses, with ψ_i = corresponding phase angles.

If the resultant phase vector is denoted by β_{res} and its phase angle by ψ_{res}, the work input can be expressed as

$$U_m = \pi T_m \beta_{res} \sin\psi_{res}$$

It is evident that maximum work is produced when $\sin\psi_{res} = 1$, or $\psi_{res} = \pi/2$.

This expression for the work input was calculated, at the design stage, for the various harmonic torques corresponding to the critical speeds expected to occur in the speed range of the engine, for both types of crankshaft and for the various firing orders. The gas-pressure components were taken from Porter's chart for harmonic components of petrol engines, published by the S.A.E. War Engineering Board.

It may be noted that the calculations were made first for the full bmep (denoted by p_e) corresponding to each engine speed and secondly for the partial-load bmep normally used under " utilization conditions " (denoted by p_u). The value of p_u can be calculated from the full-load bmep at maximum speed N_{max} from the equation

$$p_u = p_{Nmax} \times (N/N_{max})^{1.6}$$

where N = running speed for which p_u is to be calculated, N_{max} being the running speed corresponding to p_{Nmax}. This equation is considered representative of utilization conditions for petrol engines, since the power required for the tractive effort H of the motor-car is proportional to $v_p^{2.6}$ and to $p_u v_p$, where v_p = mean piston speed, so that p_u is proportional to $v_p^{1.6}$ and to $N^{1.6}$.

The results showed that (a) the three firing orders were equivalent for the harmonics of orders $3m + 3$, and (b) the firing order 1–4–3–6–5–2 was the most favourable for low values of the harmonics of orders $4\frac{1}{2}$ and $7\frac{1}{2}$, the worst critical being that of the 6th order, at 3100 to 3300 rpm (corresponding to a vehicle speed of about 100 km/hr). The 3rd order, at approximately 7000 rpm, was well above the running range and could therefore be disregarded.

Experimental Investigation

The test programme included the determination of vibration amplitudes for various running conditions of the two engines, the recording or evaluation of the gas-pressure cycle, and calculation of the corresponding torque/crank-angle diagram and tangential effort harmonics (to replace Porter's curves, which refer to an ideal petrol engine cycle with constant-volume curves and adiabatics) for the orders $\frac{1}{2}$, $1\frac{1}{2}$, etc., to the 9th order.

It was realized that there was a major unknown, i.e., engine damping, which could only be determined indirectly. Engine damping is due to vibratory friction between piston rings and liners and to the movements of the journals and crankpins in their bearings, with some additional contribution resulting from the hysteresis or internal damping of the crankshaft material during its vibratory stress cycle.

For the indication of vibration amplitudes, a torsional-vibration pick-up, incorporating a strain-gauge bridge, was fitted to the front end of the crankshaft of the test engine, i.e., at the position where the vibration is greatest. The output from this pick-up was monitored with an oscilloscope and also fed through an octave-type band-pass filter to a pre-amplifier connected to a double-beam oscilloscope fitted with a camera. One trace was used for the curve of vibration amplitude, while the other provided a 50-cps time signal. A schematic diagram of the measuring equipment is given in Fig. 3.

To satisfy the stringent test requirements, it was

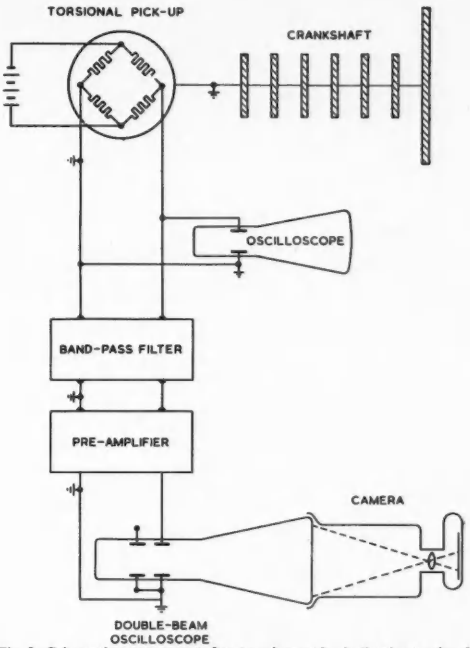


Fig. 3. Schematic arrangement of test equipment for indicating torsional-vibration amplitudes.

decided to develop a torsional-vibration pick-up capable of operating at speeds up to 6000 rpm and indicating frequencies up to 20,000 vpm or even higher, as suitable equipment of this type was not at the time available. This seismic type of pick-up (Fig. 4) consists basically of a flywheel (V) mounted on a shaft by means of roller bearings and flexibly connected to a hub on the shaft by means of two radial steel blades (L), whose inner ends are clamped in the hub, while the outer ends are held between small blocks (C) fixed on the inertia member or flywheel. The pick-up has a natural frequency of less than 7 cps, which can be varied for tests on various ranges of engines by altering the blade stiffness or the flywheel-rim inertia. It indicates the engine crankshaft amplitudes correctly, provided that the engine frequency is substantially higher than the resonant frequency of the pick-up, this being the case for the engines considered, which had calculated frequencies of about 300 cps.

There was, of course, also the effect of non-uniform shaft rotation, this effect being eliminated by means of the band-pass filter.

The two radial spring blades were provided with Baldwin SR.4 type wire-resistance strain gauges of 120 ohms each. As indicated in Fig. 5, two gauges were fixed on the opposite sides of each blade, so that one gauge would be subjected to tension while the other was in compression. The four strain gauges were connected in a bridge arrangement in such a way that the bridge output was four times greater than that of a single gauge. The inherent resonant frequency of the blades was 102,000 vpm, which is very much higher than any torsional frequency to be indicated by the pick-up.

The output from the strain-gauge bridge rotating with the shaft was obtained by means of a concentric set of copper slip-rings fitted on a disc of insulating material also fixed on the pick-up shaft, while the spring-loaded

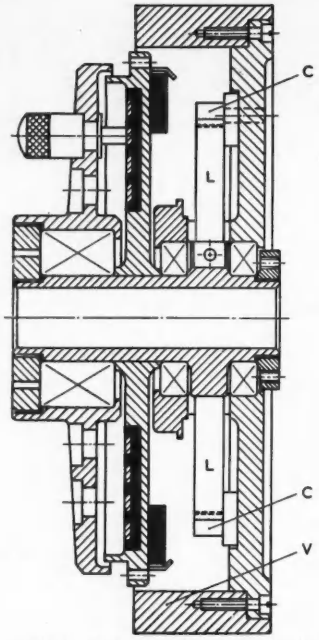


Fig. 4. Section through torsional-vibration pick-up.

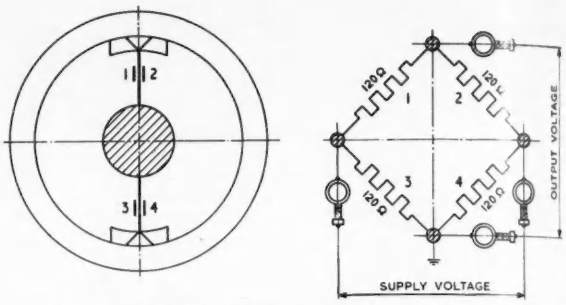


Fig. 5. Diagram showing bridge connections and position of strain gauges

brushes (two copper-graphite brushes per slip-ring, at diametrically opposite positions) were mounted on insulating material on a stationary steel cover plate supported by means of a ball bearing on the pick-up shaft. The driven end of the pick-up shaft was firmly attached to the front end of the crankshaft. Particular care was taken to eliminate the effect of centrifugal forces at speeds of 5000–6000 rpm on the leads from the strain gauges, while maintaining sufficient lead flexibility to avoid influencing blade vibrations. The rubbing velocity of the brushes, of the order of 40 m/sec, resulted in brush temperatures of 90–100°C after 30 or 40 minutes continuous running ; the temperature was reduced to less than 40°C by powerful forced-draught ventilation. Incidentally, an improved version of this torsional pick-up is now being produced, weighing less than half the present model, as a result of modifications to the strain-measuring system, the slip-rings, and brush-gear.

The bridge output of the pick-up gave a voltage of 2·43 mV/deg., and the overall sensitivity of the equipment was between 3·95 and 5·4 angular minutes per screen division on the graduated oscilloscope screen. The bridge was supplied with a voltage of 4·5 to 6·15 V, this being kept constant and measured throughout each test.

For the tests, the sparking plugs of the engine were provided with resistance-type interference suppressors, and the entire ignition system was completely shielded to eliminate high-frequency (millisecond) pulses on the oscilloscope screen, as well as low-frequency float of the trace owing to damped secondary oscillations. All the leads were screened and suitably earthed. However, a slight pulse was allowed to subsist at the ignition point of cylinder No. 1, in order to have a reference marking, although this varied with ignition advance.

Engine noise was another source of disturbance ; although less important than the torsional disturbance, the noise level of about 110 db caused structural vibrations which had a noticeable effect on the input stages of the amplifiers ; this effect was eliminated by mounting all the electronic equipment on thick layers of foam rubber and felt.

The torsiograph tests were carried out in the following order : (a) tests of engines without vibration dampers, for the three firing orders investigated, (b) tests with Lanchester-type friction dampers, and (c) tests with a bonded-rubber dynamic damper. Tests (b) and (c) were made only for the firing order 1–4–3–6–5–2. It may be noted that, for all three firing orders, the same crankcase and cylinder block were used, but the crankshaft and the camshaft were, of course, different in each case.

The Lanchester damper is well known and requires no special description. Three different versions were made, all with a moment of inertia equal to that of the main engine flywheel, but with different spring-loading arrangements, permitting variation of pressure (and hence of frictional torque) over a range of 3:1. The rubber damper of the " dynamic " type, consisting basically of a flywheel mounted on rubber, had been intended to operate at resonance, i.e., with an inherent resonant frequency equal to that of the torsional vibration of the engine crankshaft. However, it was found to have a resonant frequency nearly one-third of that expected, and that its incorrect " tuning ", therefore, was responsible for the insufficient results as regards amplitude reduction. The tests with the Lanchester dampers showed that maximum amplitude reduction (i.e., a reduction of 3:1) was obtained using the damper with the highest spring load. This was also found to be an optimum condition, i.e., when the spring load was increased still further, the vibration amplitude also increased, indicating excessive coupling between the seismic mass of the damper and its back plate.

The torsiograph tests showed that the firing order 1–4–3–6–5–2 was definitely the most favourable in regard to torsional vibration, although the others had appreciable advantages in other respects ; for instance, the order 1–6–3–2–5–4 was conducive to improved distribution of the mixture to the various cylinders, but would have made it necessary to accept an appreciable unbalance of the couples about the horizontal transverse axis. Finally, it will be recalled that all three firing orders were equivalent for the " major " orders (3rd, 6th, 9th, etc.).

After concluding the above tests, the author had the opportunity of making a similar investigation on a six-cylinder in-line petrol engine for the Mercedes-Benz 220–S motor-car.

The engine data are as follows : Bore and stroke 80 × 72·8 mm, total cylinder capacity 2·195 litres, compression ratio 7·65:1, maximum power 93·8 hp (metric) at

5000 rpm maximum speed and at a bmep of 7·7 kg/cm², with a mean piston speed of 12·1 m/sec. Maximum engine torque 14·9 kgm at 3500 rpm, with a bmep of 8·55 kg/cm². Firing order 1–5–3–6–2–4.

The crankshaft stiffness was determined as described above. The measurement of the moment of inertia of the crankshaft, however, was more difficult, owing to the shape of the crankshaft and its balance weights (Fig. 6). The crankshaft has a non-symmetrical flange disc serving as a balance weight at its free end ; there is an oblique web between crankpins 1 and 2 ; also, a balance weight between crankpins 3 and 4, at 120 deg. to the first balance weight, an oblique web between crankpins 5 and 6, and finally a third balance weight (at 240 deg. to the first balance weight) incorporated in the flywheel.

The crankshaft moment of inertia was measured in three stages, by adding symmetrical pieces to the balance weights and correcting the results, using a torsional balance and ensuring that the axis of rotation coincided with the shaft axis. The inertias of the connecting rods and pistons were determined by calculations. The Holzer table for the one-node torsional frequency of the engine-and-flywheel system, reduced to an equivalent five-mass system (Fig. 6) is given below, with J-values in kgm² and K-values in newton-metres/rad.

F = 20,800 vpm. ω = 2180 rad/sec

Mass No.	$J \times 10^3$ (1)	$J\omega^2 \times 10^{-3}$ (2)	β (3)	$J\omega^2\beta \times 10^{-3}$ (4)	$\Sigma J\omega^2\beta \times 10^{-3}$ (5)	$K \times 10^{-5}$ (6)	(7)
1	6·5	30·9	1·000	30·9	30·9	2·3	0·134
2	9·5	45·2	0·866	39·1	70·0	2·3	0·304
3	10·5	50·0	0·562	28·1	98·1	2·3	0·426
4	9·5	45·2	0·136	6·2	104·3	2·3	0·454
5	68·3	325·0	−0·318	−103·4	+0·9		

In this investigation also, the work input of the engine was calculated for the various critical orders considered, both for full bmep and for partial (utilization) bmep

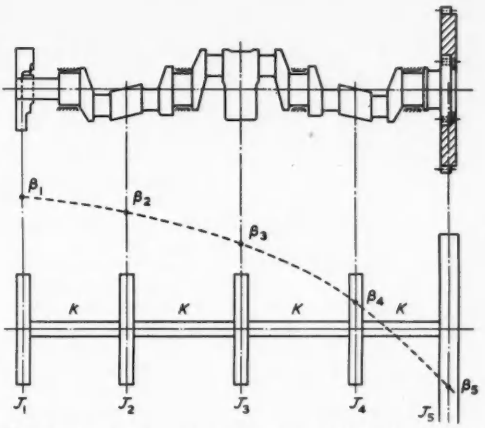


Fig. 6. Reduction of 6-cylinder in-line engine-and-flywheel system to an equivalent 5-mass system.

values. The two most dangerous orders in the running range were order 4½ at 4600–4700 rpm, and order 6 at about 3500 rpm.

The torsiograph measurements gave a vibration frequency of 21,180 vpm. The vibration amplitudes of orders 6 and 4½ were reduced to about 40% of their original values by means of a Lanchester damper.

In conclusion, it is considered that nowadays the problem of torsional vibration in vehicle engines is not very serious. However, the problem is no longer limited to the amplitudes and dynamic stresses of the shafting, but should be considered also from the point of view of the noise induced by the vibration ; this latter aspect involves questions of acoustic vibration insulation for the increased passenger comfort.

RUSSIA

The Economic Industrial Utilization of Steel Swarf

By I. N. Goncharov and E. P. Semchenko. (From *Vestnik Mashinostroyeniya*, No. 2, February 1957, pp. 80–84, 3 illustrations.)

Apart from several hundred-thousand tons of cast-iron swarf, more than three million tons of steel swarf are produced annually by machining operations in the Soviet engineering industry. Some of the steel swarf is used for steel smelting but much, if not most, is irretrievably lost.

The main reason for the reluctance of steelworks to use loose steel swarf in smelting operations is its comparatively large volume, which is more than twenty times that of the cast metal. The output and productivity of open-hearth furnaces charged with swarf are substantially reduced, while the loss through burning of the swarf in remelting amounts to more than 30%, so that fuel consumption increases together with a drop in the quality of the cast billet. Furthermore, the transport of swarf to steelworks is both costly and wasteful.

Other methods of swarf utilization have therefore been sought, of which the most widely used involves crushing the swarf for charging blast-furnaces. For this purpose, two Russian-designed swarf crushers have been built, with respective outputs of 3 and 5 tons per hour, and capable of producing crushed swarf with a maximum length of between 20 and 30 mm. However, this reconversion of steel into pig-iron is not economical, quite apart from the actual cost of swarf crushing.

Another method of swarf utilization involves the preparation of briquettes made from crushed swarf, dried at 250°C and mixed with a 15% solution of water-glass in water, the mixture being pressed in metallic moulds and then dried. However, these briquettes, weighing 15 kg and having a specific gravity of 2·0, have little strength and are not considered suitable for transport. Other binders used in making these briquettes (e.g., 20% lime, 5% cement, and 75% water) do not yield better results. Similarly, cold-briquetting under very high pressures (up to 3000 kg/cm²) applied to large masses of swarf (200 to 500 kg) has also not yielded easily transportable units.

A hot electro-briquetting process has been proposed, in which swarf in a die is heated by the passage of an electric current and is subsequently pressed. Briquettes with a specific gravity of up to 7·0 have been obtained in this way, but the power consumption of up to 200 kW per ton of swarf has proved excessive and too much loss by burning away of the swarf has resulted. In another

installation, recently put into service, the swarf is heated in a continuous furnace with a heating chamber measuring 2·6 × 3·6 × 1·5 m, a briquetting pressure of between 50 and 100 kg/cm² producing briquettes with a specific gravity of between 3·5 and 4·5.

In one plant, a solid-fuel muffle furnace has been installed for the annealing of curled steel swarf. The swarf, first heated to between 700 and 900°C, is transferred to a platform where it is rapidly spread to accelerate cooling and to reduce burning. The cooled and annealed swarf is then pressed into bales weighing 350 kg, with a specific gravity of from 3·5 to 4·5, which are charged in open-hearth steel furnaces. Based on the experience gained with this installation, another installation, now under construction, comprises a continuous furnace, using solid fuel and having a recuperator, by means of which the furnace air is preheated to 250°C. A quantity of swarf weighing up to 300 kg is fed into the furnace, where it is heated to between 700 and 750°C for from 3·5 to 4·5 min. From the furnace, the heated swarf is led to a pit, where it is quenched by a water spray at a pressure of 2 atm. The output of this plant is 6 tons per hour, of which 85% is converted into bales, 10% remains as small-size chips for blast-furnace use only, and 5% is burned away.

A special effort has been made to utilize alloy-steel swarf. The oil contained in the cutting fluid mixed with this swarf yields an excessive carbon content, and to avoid this the organic impurities are burned away in a rotary furnace at a temperature between 700 and 900°C, leading to a reduction in both the carbon and the sulphur content of the swarf. The swarf is then melted in electric furnaces to produce a suitable charge for steel smelting. However, this double processing, with its accompanying loss by burning, is not economical, and the repeated heating causes a loss of alloying elements.

It should be understood that all the above methods of briquetting require large and costly hydraulic presses and do not yield a readily usable material or even easily handled scrap. As a result, a new process has been developed in Russia under laboratory conditions. In this process, which may be said to involve the forge-welding of steel swarf, the forging so obtained can not only be used as a charge for steel furnaces but also can be directly utilized for the manufacture of machine components. Additional tests, carried out in an electric-locomotive works, have confirmed these laboratory results, and it is expected that the forge-welding method will successfully solve the problem of economical processing of swarf at its point of origin.

Forge-welding comprises the joining together of two or more pieces of metal by hammering, after prior softening of the surfaces by heating. To produce high-quality conventional forge-welds, it is necessary to remove metallic oxides from the surfaces to be joined by means of fluxes. However, attempts to weld steel swarf into solid, dense forgings, using a variety of fluxes, have produced negative results, as the pieces of red-hot swarf tend to slip past each other and do not weld together. Reducing the amount of flux added has been found to improve welding quality and, indeed, positive results have been obtained in welding without using any fluxes at all, irrespective of whether the swarf is freshly made or is largely oxidized. These results require special investigation, as it appears that the basic theoretical and practical rules applying to forge-welding are invalid in this case.

In tests carried out by the locomotive works on curled steel swarf, previously heated in a forging furnace using solid fuel, it was found easy to obtain briquettes and steel forgings of from 5 to 40 kg in weight with a single blow from a 1200-kg drop-hammer. Swarf heated to between 850 and 900°C yielded briquettes with a specific gravity of 6·7 to 7·2 but, when the swarf was heated to between 1000° and 1100°C, steel forgings with a specific gravity of 7·8, i.e., equal to the normal specific gravity of steel, were obtained. Heating of the swarf in the furnace took from 5 to 8 min, and the loss by burning away amounted to from 4 to 6%. Solid, dense steel forgings were obtained not only from mild steel but also from medium-carbon and medium-alloy steels.

In earlier tests, the steel swarf was placed in cylinders made of scrap steel sheet, into which they were compacted by hand-ramming. After heating in the furnace, the cylinder and its contents were loaded into a cylindrical die of 100 mm diameter, and the drop-hammer operated. In later tests, bales of swarf were bound with thin wire heated in a furnace, and then subjected to the forging operation. These tests also gave good results.

TABLE I : NOMINAL PERCENTAGE COMPOSITION OF PARENT METAL AND FORGED SWARF.

	C	Mn	Si	S	P
Parent metal	0·23	0·49	0·19	0·060	0·057
Forged swarf	0·15	0·52	trace	0·039	0·048

Laboratory tests on solid forgings have shown that their chemical composition differs somewhat from that of the steel from which the swarf was obtained. Some data in this connection are given in Table I, from which it will be seen that the forgings produced contain practically no silicon, that their sulphur content is greatly reduced, and that their carbon content is also substantially lower, compared with the parent metal. It was also found that the microstructure of the swarf forgings had a much finer grain than that of the parent metal.

TABLE II : MECHANICAL PROPERTIES OF PARENT METAL AND FORGED SWARF.

	Yield Strength [kg/mm²]	Ultimate Tensile Strength [kg/mm²]	Elongation [%]	Impact Strength [kgm/cm²]	Specific Gravity
Parent metal	23·7	43·1	28·4	9·3	7·8
Forged swarf	29·7	39·6	30·7	18·5	7·8

The mechanical properties of the steel obtained by the forge-welding method are in most cases higher than those of the parent metal, as shown in Table II, the impact strength being particularly remarkable. The specific gravity remains unchanged. The corrosion resistance of the forge-welded swarf was determined by testing specimens in moist air and gave results which were not inferior to those of the parent metal, while the etching of polished specimens revealed the characteristic pattern of Damascus sword-blades. Gear-wheels have been successfully machined from these forgings.

The investigations reported in this article have encouraged the design of installations embodying the forge-welding principle described. One such installation includes a rotary furnace and is designed for the production of 5 tons of forgings per hour. Preliminary estimates establish that the total cost of producing these swarf forgings will be substantially lower than the cost of swarf processing by other methods. Furthermore, preliminary tests have shown that solid briquettes can also be obtained from cast-iron swarf.

The Problem of Noise in Motor-Driven Home Appliances

By E. R. CUNNINGHAM and G. L. WOLFERT. (From *Applications and Industry* (*A.I.E.E.*), No. 29, March 1957, pp. 17–22, 8 illustrations.)

DURING recent years the ratio of material to labour cost of mass-produced products has been increasing, mainly owing to the more effective use of automatic processes. In turn, this has stimulated efforts towards producing greater output per pound of material in such items as small motors, and towards greater utility per pound in such products as home appliances. This trend brings the reduction of objectionable or undesirable sound into the forefront as a major design factor. The purpose of this paper is twofold : Firstly, to discuss, in general terms, the overall noise problem of home appliances and, secondly, to examine specifically the problem of reducing that part of noise contributed by the motor.

NOISE AS A FACTOR IN CUSTOMER ACCEPTANCE AND SATISFACTION

Objection to noise may be termed psychological, or may fall into the category of loudness. Although the prime purpose here is to discuss the problem of loudness, a few examples of psychological annoyance are in order.

To borrow an example from the automotive industry, many individuals accept, with some feeling of pleasure, the low-frequency exhaust roar accompanying acceleration (suggesting power), but are quite perturbed by a slight ticking in the motor (suggesting improper functioning) or similarly by an elusive rattle under the dashboard. The sound level of one can be measured quite easily with common sound-measuring instruments ; the other is so low in relation to the accepted background noise that the use of a narrow-band analyser and other specialized equipment is necessary for detection.

Similar problems exist in the field of home appliances where various and sundry noises, such as relay buzz, intermittent pump and gear noises, intermittent clinking of buttons on the revolving drum of a dryer, etc., can be quite annoying to some people when the appliance is located in close proximity to the living quarters.

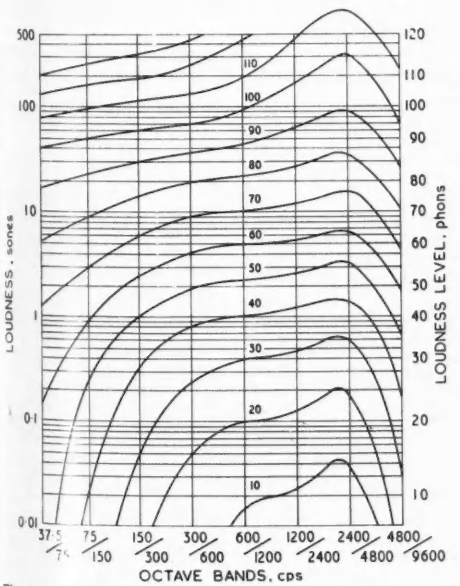


Fig. 1. Relationship between sound-pressure level, phons, and sones.

Generally, it is often difficult to determine the factors related to annoyance, since such items as previous conditioning of individuals are involved, as well as the character of the noise.

Of perhaps more immediate concern to motor and appliance manufacturers is the actual loudness of the sound produced by their products.

To describe loudness, conversion of octave data to " phons " (a partially subjective means of describing loudness in decibels, and termed " loudness level ") or to " sones " (a subjective unit termed " loudness ") may be made. Sones are not expressed in decibels, but in such units that a doubling of the loudness, as determined subjectively, is represented by a doubling in the number of sones. Fig. 1 shows the relationships between sound-pressure level, phons, and sones. Another important consideration in evaluating noise data is that of speech interference and telephone usability. The arithmetic average of the sound-pressure level in the three octaves, 600/1200, 1200/2400, and 2400/4800 cps is generally used for this determination ; although in such cases where the sound-pressure level in the 300/600 octave is more than 10 db above that in the 600/1200 cps octave, it should also be included in the arithmetic average. This arithmetic average is often referred to as the " speech interference level".

Although the level at which normal conversation can be easily carried on in the home depends on many factors, such as separation distance of individuals and the room acoustics, generally, whenever the speech interference level exceeds 55 to 60 db, normal conversation at separation distances of 3 ft or more becomes difficult, as does telephone usability.

There are, of course, important factors governing noise acceptance in the home which are not directly under the control of the manufacturers. These are :—

(1) Ambient or background noise level prevailing in the appliance area.

(2) Acoustic properties of the room in which the appliance is located.

(3) Floor construction on which the appliance is mounted.

The first of these factors is quite obviously important. Other conditions being equal, for example, an appliance will sound relatively quieter in a busy department store than in a small suburban store, since the background noise available to mask the appliance noise is generally much higher in the first case.

The acoustic properties of the room are also important. Reference to Fig. 2 shows the difference in sound-pressure level which would exist as a function of distance from a non-directional noise source in rooms having different acoustic properties.

The type of floor construction on which the appliance is mounted can have a definite influence on resulting loudness. A wooden floor, for instance, is more flexible than a solid concrete floor, and any vibration coupled from the appliance to the floor can be re-radiated from the floor and also transferred through joists and studding to other

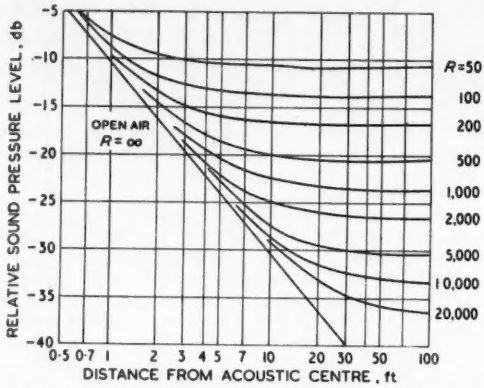


Fig. 2. Sound-pressure level relative to power level for a non-directional source of different values of room constant R as a function of distance from source.

$R = \alpha S/(1-\alpha)$, where α = average absorption coefficient of room surfaces and S = total area of boundary surfaces [sq ft].

rooms, where the resulting noise may be a cause for dissatisfaction.

These are some of the factors involved in obtaining customer acceptance. More specifically, the concern here is with the contribution of the motor to the appliance noise level and methods for reducing motor-induced noise.

Nature of Motor Forces

The electromagnetic forces associated with a single-phase induction motor can be broadly classified as follows :—

(1) Slot harmonic forces.
(2) Dissymmetry harmonic forces.
(3) Torque pulsation forces.
(4) Solenoidal pulsation forces.

The slot harmonic forces occur because of the existence of a finite number of rotor and stator slots.

With the notation S_r = number of rotor teeth, $s = (n_s - n)/n_s$ = slip, n = actual motorspeed, n_s = synchronous speed, f = line frequency, and P = pairs of stator poles in motor, the basic frequencies involved are $S_r\ (1-s)\ f/P$, $S_r\ (1-s)\ f/P + 2f$, and $S_r\ (1-s)f/P-2f$.

Both the pole structure and frequencies associated with these forces can be controlled by proper choice of rotor and stator slot numbers, within, of course, the limits of proper electrical performance and ease of manufacture. The magnitude of these forces increases with increasing air-gap flux density. To limit the magnitude with the increased flux densities, motor manufacturers utilize such methods as proper rotor tooth number, rotor tooth spiral, and closed slot rotors.

Dissymmetry forces occur because of the existence of electrical and mechanical dissymmetry. Included are such items as imperfect rotor castings, variations of bridge thickness around the rotor circumference, and eccentricity of the rotor with respect to the stator bore.

Torque pulsations are inherent in a single-phase induction motor and occur at a basic frequency of $2f$. A permanent split-phase motor can have considerably reduced torque pulsations. Thus, when the rotor bars are skewed or spiraled, a component of this force acts in the axial direction of the motor. The axial component of this force can be reduced by herringbone-skewed rotor bars.

The force exerted by a magnetic field is always such as to maximize the magnetic energy and minimize the electric energy. Thus, an axial solenoidal force acts so as to reduce the air gap between rotor and stator to an effective minimum, which position is generally referred to as magnetic neutral. This force pulsates at a frequency of $2f$. The magnitude of this force depends upon the air-gap flux density, relative lengths of rotor and stator, and rotor-to-stator axial positions.

There are, of course, mechanical forces, such as inertia forces due to rotor unbalance or axial forces caused by rotor-to-stator thrust surface wobble, which can be of concern when of sufficient magnitude. However, in most cases these are manufacturing problems which are adequately controlled.

Nature of Vibrations and Noises Produced by Motor Forces

The forces within motors which have just been described act on the various parts to cause vibration. Vibration as such is not necessarily objectionable, but it may be so if it effectively couples to the air so as to cause excessive noise. This vibration may result in sound radiated directly from the motor, or may be transmitted through the mounting supports to structural elements of the appliance, from which it may be considered to be indirectly (with respect to the motor) radiated as sound. The amplitude of a sound wave depends upon the amplitude of air particle vibration which, in turn, depends on (1) the magnitude and frequency of the vibrating part and (2) the effective coupling of the vibration to the air.

With respect to the effective coupling, high-frequency vibration can be coupled effectively to the air by relatively small surfaces, while lower-frequency vibration requires larger dimensional surfaces for equally effective sound radiation. For example, a fractional-horsepower motor having a particular magnitude of 120-cps vibration will produce very little sound at 120 cps. However, if this vibration is transmitted to the relatively large sheet-metal housings of appliances which provide effective surfaces for the coupling of such vibration to the air, a relatively high level of sound at 120 cps will be produced. Thus, the transmission of motor vibrations to these large surfaces is one of the vital factors in determining the noise level of the appliance.

The nature of the vibrations produced by electromagnetic forces are as follows :

The tooth frequency forces, with proper choice of slot numbers, cause little or no rotor flexure, but cause the stator to vibrate in a radial plane by producing changes in shape. The inertia forces developed by this vibration are cancelled out within the motor frame, and thus do not produce external reactions. The noise generated by this movement of the stator is transmitted to the ear directly from the motor frame and, with most motor-mounting systems, is not coupled to the appliance. These vibrations are usually highest in amplitude at or near the four-node resonant frequencies of the frame, usually ranging from 1100 to 1600 cps. The noise produced is generally reduced by the proper design of motor parts, so as to separate, as much as is practicable, force frequencies and motor resonances.

Forces caused by motor dissymmetry can also act to produce directly radiated motor noise, especially in the vicinity of the rotor and stator resonant frequencies. However, more important from the standpoint of vibration coupling to the appliance, such dissymmetry often introduces unbalanced air-gap forces, causing rotor flexure, especially in the vicinity of rotor resonance (usually 400

to 800 cps). Such rotor vibration can in turn flex the end bells. Thus, a mounting system utilizing through-bolts can, if not properly designed, transfer this vibratory energy to the appliance.

The torque pulsation forces generated by the rotor current and air-gap flux cause the rotor and stator to vibrate relative to each other about the shaft axis at a frequency of $2f$. Since the stator is usually round and concentric with the shaft, the torsional vibration of the motor alone acts in shear on the air and hence is not radiated as sound. Surfaces perpendicular to the direction of vibration are too small to radiate effectively the low frequency involved. However, this vibration can be effectively coupled to the appliance and hence radiated as sound if proper vibration isolation is not provided.

The torque pulsation forces acting on the rotor can have an axial component of force, unless the skew is of a herringbone pattern. This axial component causes the rotor to push against the motor-thrust bearing. If the motor has free axial end-play relative to the end shields, this axial force may cause the rotor to vibrate axially, transmitting vibration from the end of the motor to the supports and the appliance.

The solenoid force acting on the rotor and stator behaves in much the same manner as does the axial component of the torque pulsations, and is usually kept low in amplitude by careful rotor-to-stator axial alignment and/or by the proper design of rotor thrust collar and end-shield thrust surfaces.

Methods for Reducing the Amount of Vibration Transmission from Motors to Appliances

Some methods for reducing the amount of vibration transmitted from a motor to the associated appliance are as follows :—

(1) To increase the mass of the part of the motor to which the forces are applied.

(2) To add a tuned vibration absorber to the motor or vibrating part.

(3) To add an inertial-friction vibration damper to the motor.

(4) To use vibration isolation between the motor and the appliance.

(5) To eliminate any vibration caused by too low a stiffness of the " rigid " type of motor supports.

The possibility of reducing the amplitude of the applied forces should not be overlooked. Changes in the electrical design of a motor to obtain modified 2-phase operation with a run capacitor will reduce torque pulsation forces. However, the capacitor is usually more expensive and takes more space than isolation mountings, and the maximum reduction is limited.

The possibility of increasing the mass of the motor is opposite to the basic trend in design which results in smaller and lighter motors to obtain greater output per unit of cost.

The application of a tuned vibration absorber may be possible. Such a device is essentially a spring and a mass which are attached to the motor, so that it is free to vibrate in the same direction as the motor. The natural frequency of this system is made the same as the frequency of the applied force, but the mass vibrates 180 deg. out of phase, so that the applied force is opposed by an equal and opposite force and cancelled out. The advantage of a well-designed tuned vibration absorber is that it eliminates practically all of the vibration of the body to which it is attached for a particular frequency. Its disadvantages, however, are numerous. Space and material are required, resulting in higher cost ; long fatigue life is nto easily obtained ; the device must be tuned accurately to the applied force frequency ; inherent damping must be low; and resonant frequencies on both sides of the force frequency are created. Also, the absorber must be designed to withstand the peak vibration which it may have to counteract ; otherwise, it may be damaged.

The inertial frictional vibration damper consists of a mass fastened to the motor in such a way that relative movement is possible. It is, however, accompanied by frictional resistance which converts vibrational energy to heat. This device is in a class with the tuned absorber but is less versatile and suffers from a limited life due to possible wear, unless fluid friction is used. It requires, and may lose, adjustment, operates only above a minimum value of the applied force, and is relatively expensive.

The next method is vibration isolation, which consists of supporting the motor, relative to the appliance, by springs. Thus, the motor is allowed to vibrate in the direction of the applied force, allowing the inertia forces of the vibrating motor, as well as the supporting springs, to oppose the applied forces. As the freedom for vibration increases, the inertia forces increase, thus decreasing the transmitted vibration.

The degree of isolation obtained is defined in terms of the transmissibility T, which is the ratio of the amplitude of the force transmitted by the mountings to the amplitude of the force applied to the motor. The equation for T when damping in the mountings is neglected is (assuming the point on the appliance to which the flexible mounting system is attached to be perfectly rigid)

$$T = \frac{1}{r^2 - 1} \qquad (1)$$

in which r, the isolation ratio, is the ratio of the frequency of the disturbing force f_o to the natural frequency of the spring mass system formed by the mountings and the motor f_n. The equation for f_n is

$$f_n = 1/2\pi \sqrt{K/M} \qquad (2)$$

For linear vibrations and for torsional vibrations

$$f_n = 1/2\pi \sqrt{K_r/I} \qquad (2a)$$

where K is spring constant of mounting, M is mass, and I is polar moment of inertia of the motor. A plot of the transmissibility T, for various values of the frequency ratio r, is given in Fig. 3.

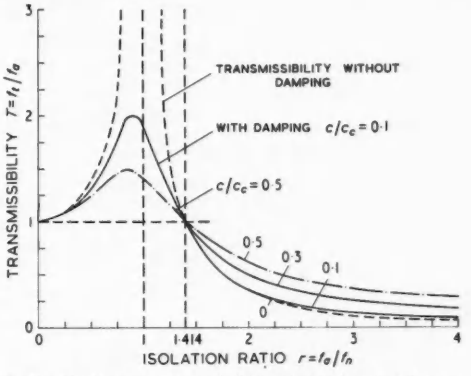


Fig. 3. Graph showing transmissibility T plotted against frequency ratio r, with different amounts of damping.

Since T depends on f_n, it is a function of K and of M, so that the isolation provided by a mounting only has meaning in connection with a given mass. Actual mountings all have some hysteresis or damping, ranging from a very low value for steel springs to a relatively high value for rubber and cork. The transmissibility with damping (assuming again that the point on the appliance to which the flexible mounting system is attached is perfectly rigid) is given by the equation

$$T=\left[\frac{1+\left(\frac{2cr}{c_c}\right)^2}{(1-r^2)^2+\left(\frac{2cr}{c_c}\right)^2}\right]^{1/2} \quad .. \quad .. \quad (3)$$

where c=damping factor and c_c=critical damping.

This equation in effect says that, with damping, T depends on the frequency ratio r and the damping factor. The dotted curve in Fig. 3 gives T for a value of damping commonly used in rubber mountings and shows that, for frequency ratios greater than 1·414, damping increases transmissibility or decreases isolation ; for lower frequency ratios in the amplification range, however, it reduces transmissibility towards the value of 1·0 obtained by a perfectly rigid mounting. The decreased isolation caused by damping can be compensated for by a slight increase in the isolation ratio, as shown by Fig.1.

Provision of adequate isolation of all the motor forces from the appliance is obtained by providing a value of K in the mountings supporting the motor for each direction of vibration which will yield a resonant frequency sufficiently lower than the frequency of the force causing the vibration. In practice, other requirements on the mountings, such as resistance to belt pull, must be considered.

The degree and direction of isolation required for each disturbing force depend (1) on the efficiency of the appliance as a radiator of received vibration ; (2) on the relation of the frequencies of vibration transmitted to the appliance to the resonant frequencies of the appliance ; (3) on the allowable radiated noise level for the appliance; and (4) on the magnitude of the disturbing forces in the motor.

The effectiveness of vibration mountings can be increased by attaching the mountings to nodal points or points on the motor with the least vibration, such as close to the shaft for the torsional mode. Mountings should be attached symmetrically about, or in the plane of, the centre of gravity of the motor, to keep the possible degrees of freedom to a minimum and the mounting simple and low in cost.

The last method of reducing the magnitude of vibration transmitted from the motor to the appliance is the elimination of vibration amplification, which is distinguished from vibration isolation in that vibration isolation reduces the transmissibility below 1 (the transmissibility for a rigid mounting), whereas reduction of vibration amplification reduces the transmissibility from values appreciably greater than 1 to unity. This distinction is made because what appears to be a rigid mounting at first glance may actually be a mounting with sufficient compliance to provide an amplification of vibration over that of a rigid mounting, and in such cases stiffening of the mounting will provide an appreciable and possibly sufficient reduction in transmitted vibration. In general, however, a truly rigid mounting system is difficult to attain since, from a vibration standpoint, the appliance itself must be considered as a series of spring-coupled masses.

Relation of Vibration Response Characteristics of Appliance and Associated Motor

Each part of every appliance has various mechanical resonant frequencies, and these are determined by manufacturing variations, as well as by design. Slight variations which are otherwise insignificant can cause appreciable variations in the resonant frequencies of flat plates. The point at which vibration is applied and the stress in the part can also vary the response characteristics.

The use of vibration isolation between assemblies, damping materials, and the type of connections also affect the manner and degree with which an appliance will respond to the vibrations applied by the motor.

Besides the mechanical resonances, parts of appliances, such as washer tubs, may form or contain cavities which have acoustic resonances similar to a Helmholtz resonator or an organ pipe. When the resonant frequencies of such cavities are near the force frequencies applied, considerable noise amplification will occur, especially when the appliance is operating " unloaded ". If the frequencies of the applied forces coincide or are near the resonant frequencies of the appliance, then the radiated noise level will be particularly high, unless the vibrations transmitted to the appliance are very low, such as those obtained by a high isolation ratio.

Many of these resonant frequencies are difficult to predict in the design stage. Of course, inherent stiffness or damping can be designed into various critical parts within certain limits.

The wide range and high amplitude of vibrations which can be transmitted from a motor to the appliance and the inherent sensitivity of many parts of appliances to a wide range of vibrations of relatively low magnitude result in a relation of a complex nature between the motor and appliance. However, if one of the available methods for reducing the amount of vibration transmitted from the motor to the appliance, particularly isolation, is effectively utilized, then the noise level radiated by the appliance due to motor vibration can be kept lower and more uniform in value.

The Photography of Electron-Optical Images

(*Concluded from page 251*)

cording or positive film, such as used in the film industry, will come up to these requirements, so that, if it is not possible to obtain films which are specially produced for electron-microscopy, this type of film may be used as a substitute.

No special requirements are made on the enlarging paper and the material for intermediate negatives. Enlarging papers from reputable manufacturers are all quite suitable. It is, however, recommended that the same make should always be used, since corresponding grades of different manufacturers vary. Besides colour-blind half-tone copy material, lantern plates may also be used for the intermediate negatives.

Finally, the importance should be emphasized of carrying out all photographic processing under identical conditions. Temperatures and exposure times should always be checked, to ensure absolute uniformity. Photographic processing will thus become a matter of unfailing routine. If any alteration is to be introduced, test exposures should first be made to establish its effects, ensuring that any visual electron-optical observation is photographically recorded correctly.

The Photography of Electron-Optical Images

By J. SMITS. (From *Philips serving Science and Industry*, Vol. 4, No. 3, 1957, pp. 44–56, 10 illustrations.)

This article deals with the procedure for photographing the images obtained with an electron microscope and the subsequent processing of the photographic material. Particular attention is given to the points differing from normal photographic processes.

CONTRAST in the electron-microscope image is, in general, not very high and, since it is necessary to have a certain contrast in the image to make clear observation possible, it is desirable to obtain a gain in contrast through the photographic process. The negative material used must therefore be rather high in contrast. It should, however, be borne in mind that high-contrast photographic materials have a small exposure latitude and consequently cannot adequately reproduce incidental extremes of contrast. Care should therefore be taken not to carry this too far and not to use any extremely high-contrast material, all the more so because it is always possible to achieve an increase in contrast by printing on a hard positive material. A suitable compromise should always be aimed at.

As the negatives will usually have to be enlarged, it is desirable to use a fine-grain negative material. Such fine-grain materials have a low sensitivity, which is, however, no great disadvantage when used with electron microscopes, in which only inanimate and immobile objects are observed.

A question that often arises concerns the advantages and disadvantages of miniature film versus large-size photographic plates. The advantages of 35-mm miniature film are the possibility of making a series of exposures easily and conveniently, without having to change the camera or cassette ; operation is cheap ; a large number of exposures may be processed simultaneously and under identical conditions ; and the filing of negatives requires only a small space.

The advantages of large-size plates are the possibility of making prints showing a sufficient amount of detail, without enlarging ; the making of single exposures, which can be processed immediately ; the possibility of making bigger enlargements without the grain of the photographic material becoming noticeable ; and a greater choice of normally available photographic material.

With regard to the question of the final enlargement necessary to show certain details, if it is desired to distinguish two points on a photograph which are 25 Å apart in the specimen, then it is necessary for the final enlargement of the photograph to be × 80,000. This is because, for good observation, these two points must be at least 0·2 mm apart on the print. This final enlargement of × 80,000 may be obtained in two ways : An exposure can be made on miniature film with an electron-optical enlargement of × 10,000, and this exposure is then photographically enlarged eight times. It is also possible to make an exposure directly on a large-size plate with an enlargement of × 80,000. In neither case will the grain of the photographic material be troublesome. A × 8 enlargement of fine-grain film may be regarded as quite moderate, while with the plate no subsequent photographic enlarging at all is involved. The advantage of the method using miniature film is that the electron-optical enlargement is much smaller, so that much more light is projected onto the film, permitting a reduction of the electron intensity, so that the specimen runs less risk of being burned.

Since, in electron microscopy, a fine-grain photographic material is used, it is desirable further to improve

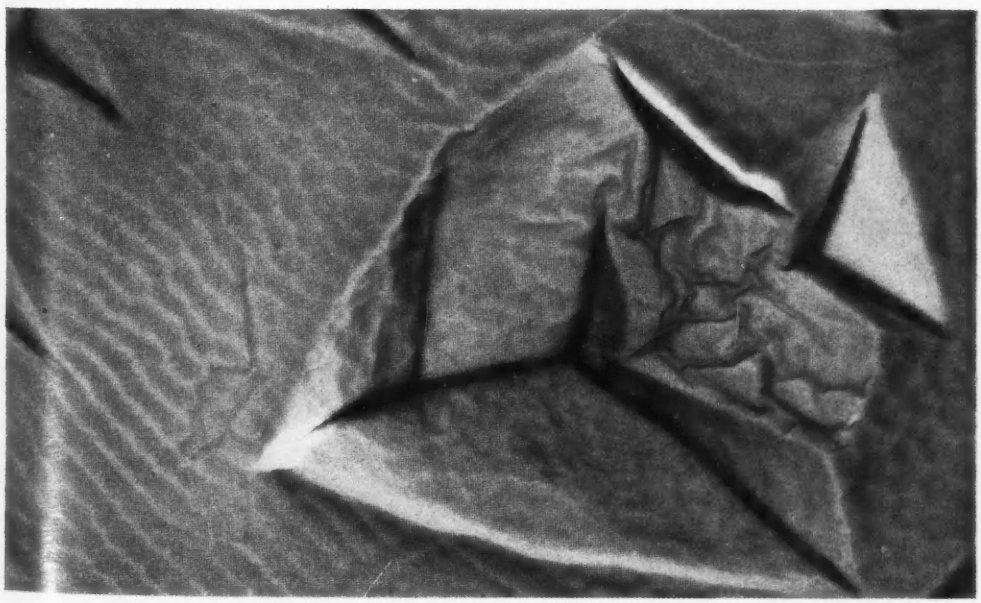


Fig. 1. Etched aluminium. Carbon replica (× 25,000).

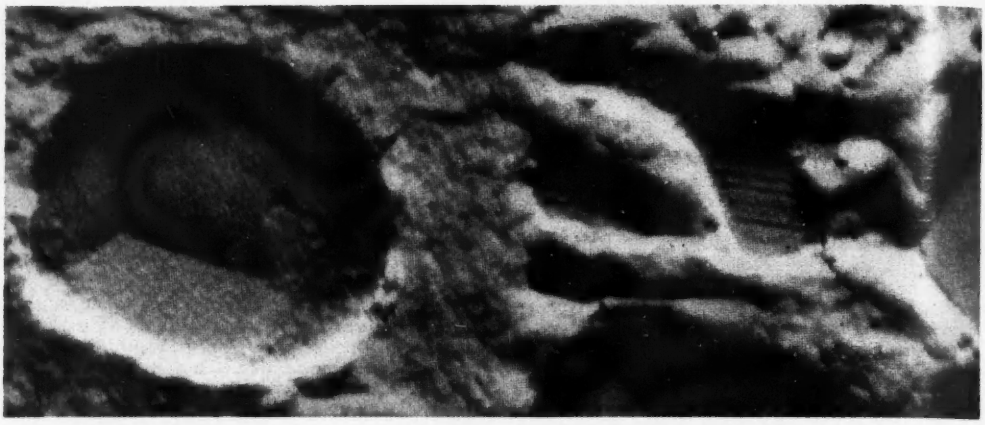


Fig. 2. High-carbon steel, carbide precipitate, and different phases in a Formvar replica. Chromium-shadowed (× 37,000).

this property by processing the material in a fine-grain developer. The so-called ultra-fine-grain developers, as usually recommended for normal miniature photography, are not suitable for this special work, since these developers are rather too soft-working for this purpose. The film, which must have a considerable degree of contrast, would lose too much contrast if processed in these developers. It is, however, desirable to use a developer which gives a fine grain without affecting the contrast too much. Good results are obtained with a metol-hydroquinone-borax developer. If a lower electron-optical enlargement and hence a greater subsequent photographic enlargement is used, it is desirable to keep the grain somewhat finer. Suitable developers exist for this purpose and permit enlargements of about × 15 with fine-grain film. The gradation is, however, softer than with the metol-hydroquinone-borax developer, though it may be offset by slightly prolonging the developing time.

It should be pointed out that it is desirable to filter the developer before use, and to take every possible care to work cleanly. Even small impurities can damage the negatives, and this will be especially obtrusive at relatively high enlargements. Every precaution should be taken to avoid damage during fixing, washing, and drying. A hardening fixative is recommended for the films, which will then be less liable to damage during washing and drying. Likewise recommended is the addition of a wetting agent to the final washing bath, to prevent the formation of lime rings when the film is drying.

Taking into consideration the very wide differences in the nature of specimens, it is not possible to give precise indications regarding exposure times for electron-optical photography. Exposures may quite well vary from 1 up to 20 sec. In general, exposures around 5 sec are most common. Both very long and very short exposures are better avoided ; with long exposures it is possible that external influences cause instability of the image, while, if short exposures are made, it is difficult to keep these reproducible.

The enlargement of micro-exposures should offer no difficulties for those with some photographic experience. Enlarging micro-photographs is not different from the normal darkroom procedure. All bromide papers from reputable manufacturers are suitable, the choice of a grade of paper being primarily dependent on the preference of the microscopist ; it is recommended, however, that this grade should not be too soft. It is generally known that it is easier to perceive details when there is a great contrast difference, and these contrasts can be achieved by enlarging on a hard bromide paper. It will then be seen,

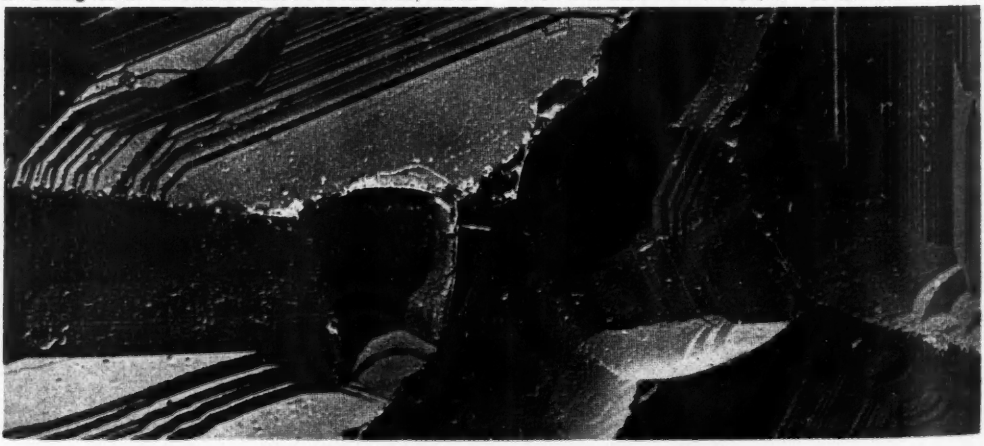


Fig. 3. " Ferroxdure " replica, shadowed with palladium. (× 200,000)

however, that, in other parts of the negative which are much darker or lighter, details are no longer visible, since these parts are reproduced as white or black respectively. If a second enlargement is made with a different exposure, however, it will be possible to make the details in these parts visible. A number of enlargements from the same negative are made in such a way that the details on different density levels are clearly shown on the various enlargements. The whole range of the negative is thus, as it were, divided into several sections.

In micro-exposures which are shadowed by means of a shadow-casting apparatus, it is desirable to have a final enlargement showing these shadows as black. Artificial shadows in the specimen are more transparent to electrons than the other parts. The shadow material is not deposited at these points, so that here the electrons are hardly scattered at all. On the negative these shadows are thus shown as black. On an enlargement from this negative these shadows will appear as white. It is therefore necessary to introduce a further photographic stage between the first negative and the final enlargement. It is usual to make an " intermediate " negative of such exposures, this intermediate negative usually being four or five times enlarged, compared with the first negative, and the final enlargement required obtained by enlarging this intermediate negative onto paper. A half-tone copying film can best be used for making these intermediate negatives; this material has rather high contrast, but possesses a sufficient range to be able to reproduce all the details in the negative, and is also sufficiently fine-grained. The developers recommended by the manufacturers for this type of material may be used, but it is also possible to process it in the same developer used for the original photomicrograph, as produced in the camera. In the latter case the grain will be a little finer, while the gradation will be rather softer. In general, it will offer some small advantage.

As already stated, a fine-grain material of rather high contrast is to be preferred for electron-optical photography. The material does not need to be colour-sensitive, since a colour-blind emulsion has the same sensitivity to electron radiation as a sensitized emulsion. A colour-sensitive film, orthochromatically or panchromatically sensitized, is indeed undesirable, since such a film has to be processed either in dark-red light or in complete darkness. As regards gradation, this will nearly always be considerably lower for an exposure with electrons than for an exposure to visible light. A material should be chosen which has, for visible light, a gradation value γ of about 3. Films with a γ-value of 4 to 5 are generally too hard and less suitable. It should be mentioned, moreover, that, for normal landscape or portrait photography, negative material with a far lower γ-value (0·7 to 0·8) is used. The resolving power should be about 150 lines per millimetre. Although the resolving power is mainly decided by the size of the silver bromide grains composing the sensitive layer, the thickness of this layer is also important. A small thickness improves this resolving power. In general, it may be said that a fine-grain re-

(Concluded on page 248)

FRANCE

Flame Stabilization by means of Obstacles

By G. MATTON. (From *La Recherche Aéronautique*, No. 57, March/April, 1957, pp. 11–17, 12 illustrations.)

THE relations hitherto used for graphs of experimental curves of extinction limits for flames impinging on obstacles generally show considerable scatter, owing to lack of knowledge of the stabilizing region and the velocity of lines around this region. It appears that the configuration of the wake in the presence of a flame is similar to that obtained under cold flow conditions with the same obstacles provided with an axial splitter plate on the downstream side. In the following it is shown that the measurement of the base-pressure drop with a flame can be used to relate the velocity V' along a streamline to the approach velocity, and the wake width d' to the width of the obstacle. By means of these new data, for a variety of two-dimensional obstacles it is possible to represent the extinction limits by a single curve in a diagram relating V'/d' to the air/fuel ratio A/F.

It is known that the wake behind an obstacle is considerably modified by the presence of a flame.[1] Instead of the usual flow pattern with alternating vortices, there is a stable " recirculating region " with two eddies or vortices in opposite directions which reverse the flow of fresh gases and hot combustion products towards the obstacle. However, this wake breaks up when, for a given air/fuel ratio A/F of the mixture, a critical flow velocity V (termed the " extinction limit ") is exceeded, and a partial or complete blow-out of the flame occurs as a result. A relation of the type $V/d^{\alpha} = f(A/F)$ gives a fairly good representation of experimental results for a family of similar obstacles, but the exponent α, which is determined empirically, also depends on the mounting and testing arrangement. For thin obstacles, the value of α is about 0·5, whereas $\alpha = 1$ gives fairly representative curves for thicker obstacles [2,3,4,5].

The origin of these two distinct values of α is attributed to differences in flow conditions[6] around the obstacle, the value of 0·5 corresponding to boundary layers which are laminar, and the value of unity to layers which are turbulent at the separation point. The critical Reynolds number determining the change from one condition to the other is a function of the scale and intensity of turbulence existing in the inlet section of the duct, and varies, therefore, with each particular installation.

The influence of flame-stabilizer shape and profile has been observed only in industrial-type installations.[4,5] It can be characterized by a drag coefficient C_e measured in the presence of a flame in contact with the obstacle. The value of C_e has been found to be independent of the flow velocity and composition of the fresh gases, but it is definitely lower than the usual drag coefficient without a flame for the same profile, measured under the same conditions. With the hypothesis of spontaneous ignition of the fresh-mixture stream filaments in contact with the hot gases of the stabilizing region, estimations have been made[5] of the heat exchanges occurring through the surface defined by the stream filaments supported on the separation line, the area of this surface being regarded as proportional to the drag coefficient C_e. Improved correlations have been obtained by using, instead of the

relation $V/d = f(A/F)$, the modified relation $V/dC_c = f(A/F)$, for the graphical representation of extinction limits of various bodies, including circular and semi-circular cylinders, 90-deg. wedges, and flat plates. A similar correlation is obtained by using graphs with V/D plotted against the A/F ratio, where D is the mean width of the wake, evaluated from photographs of the flame; there is, in fact, somewhat less scatter for flat plates.

These representations suffer from the defect that the use of a drag coefficient to characterize the wake, or of a wake width evaluated from flame photographs, introduces considerable uncertainty, particularly since the corresponding theory requires a measurement of velocity along the streamlines with micro-probes located tangentially to the flame front. In the absence of a correct determination, it has been assumed that this velocity could be replaced by the approach velocity. However, it has now become possible to evaluate the width of the wake and the velocity along a streamline, as a result of investigations by Roshko[7,8,9], from a simple measurement of base pressure taken on the downstream surface of the obstacle. It is of interest to consider briefly Roshko's theory on the study of wakes:—The basic hypothesis of Kirchhoff is that the pressure in the wake is uniform. If it is assumed that this pressure is that of the undisturbed flow on the upstream side, the velocity V' along the streamline becomes equal to the upstream velocity V_∞ at infinity, and, in the hodograph plane, the streamline is represented by an arc of a circle forming a simple geometric figure with the image of the obstacle, so that an elegant solution of the problem is obtained. Fig. 1 illustrates this solution for the particularly simple case of a flat plate.

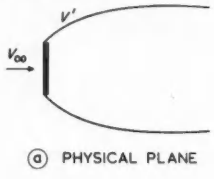
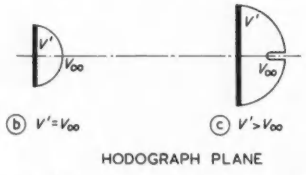


Fig. 1. Velocity field around a flat plate.



In fact, however, experience shows that the pressure p' at the base of the obstacle is definitely lower than p_∞, although the pressure in the wake is indeed uniform. Roshko's improvement of this aerodynamic theory of bodies with a wake consists of taking for p' its experimental value, and defining a " base-pressure coefficient "

$$C_{ps} = (p' - p_\infty)/\tfrac{1}{2}\rho V_\infty^2 = 1 - (V'/V_\infty)^2 = 1 - k^2$$

where k is the base-pressure parameter.

The velocity at the separation point is therefore $V' = kV_\infty$ and remains constant over a certain length along the streamline. In the hodograph plane, the end-point of the velocity vector still describes an arc, but compliance with conditions at infinity result in a " notch " in the vicinity of the direction parallel to the free streamline velocity (Fig. 1c). In the physical plane, this hodograph corresponds to a wake of width d' which is a function of parameter k, i.e., of excess velocity.

The pressure distribution on the obstacle and the drag obtained by integration are in good agreement with experimental observations[8], and the treatment can be extended to bodies of other shapes, e.g., wedges or cylinders[7,9]. Fig. 2 shows curves of the coefficient of spread d'/d of the wake (d' = width of wake, and d = width of body) as a function of parameter k. It can be seen that the wake narrows considerably when the streamline velocity increases, i.e., as base-pressure decreases.

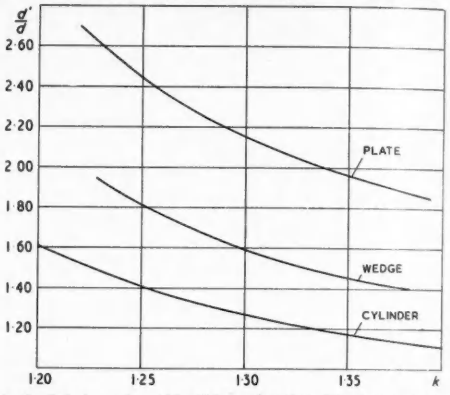


Fig. 2. Relative wake width d'/d as a function of base-pressure parameter k, according to Roshko.

The marked decrease in the drag coefficient of the obstacle when a flame is held in its wake corresponds to a pronounced increase in base pressure, owing to a complete reorganization of the turbulence pattern. From the aerodynamic point of view, the wake of a body supporting a flame is little different from that of a conventional body which is extended on the downstream side by an axial flap or splitter plate of finite length, situated along the plane of symmetry. Experience confirms that this plate prevents establishing conditions with alternating eddies and leads to an increase in base pressure. Roshko's theory also gives a very correct determination of the aerodynamic configuration of the wake. The corresponding results will now be applied to flame stabilizers.

Experimental Investigation and Test Results

To obtain experimental conditions similar to those occurring in the combustion chamber of a jet engine or in a reheat tube, all experiments were carried out with a mixture of air and atomized kerosene. The air was preheated to a temperature of 500°C in an auxiliary chamber situated ahead of the test section. The fuel was injected sufficiently ahead of the obstacle for the fuel/air mixture to be homogeneous at the obstacle level; the fuel/air ratio was determined, taking account of the fraction of fuel used in the preheating chamber. The test chamber was of rectangular cross-section (100 × 150 mm), and the two-dimensional obstacle was located at 200 mm from its outlet section, across the minor axis of the chamber. Provision was made for the possibility of cooling the side walls on the downstream side of the obstacle.

The reference velocity V (by definition the mean velocity in the inlet section of the test chamber) was

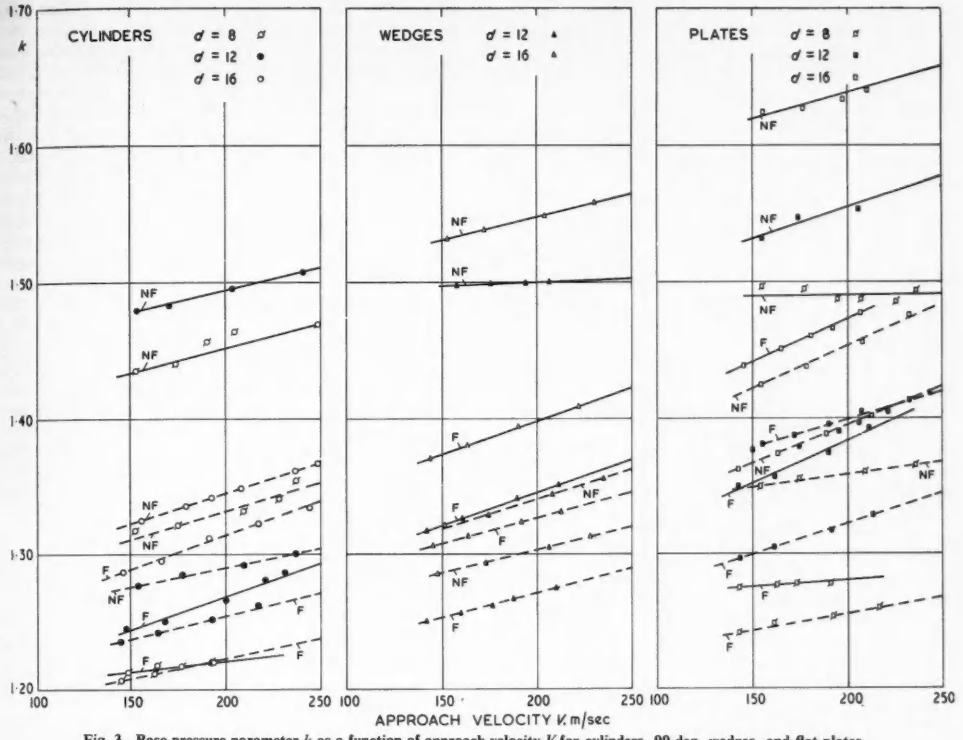


Fig. 3. Base-pressure parameter k as a function of approach velocity V for cylinders, 90-deg. wedges, and flat plates.
Solid lines : $L = 100$ mm. Dotted lines : $L = 80$ mm. (F) With flame. (NF) Without flame.

calculated from measured flow rates of air A and fuel F, as well as from the pressure difference Δp of a differential manometer connected to a pitot tube situated at a previously chosen position for indication of the mean velocity.

From the measurement of the pressure deficit $\Delta\psi$ in the wake of the obstacle, the base-pressure coefficient was evaluated as $C_{ps} = \Delta\pi/\Delta p$ and the base-pressure parameter k along the streamline was determined as

$$k = \sqrt{1 - (\Delta\psi/\Delta p)}.$$

It may be noted that this experimental value of k depends on the influence of the walls and differs from the limiting value k^* for an obstacle in a free stream. This experimental k-value is used to obtain the real velocity along the streamline in a test installation, and is therefore the value to be employed in correlation formulae. However, limiting values of k^* were also calculated, in order to verify the consistency of the measurements.

As regards the types of bodies investigated, the study was confined to obstacles of high aspect ratio, for which the field of flow is substantially two-dimensional. The shapes chosen were flat plates, circular cylinders, and right-angle wedges, with thicknesses of 8, 12, and 16 mm. The first tests were made with bodies extending across the entire width L of the stream ($L = 100$ mm) and equivalent to obstacles of infinite aspect ratio. In these tests, only aerodynamic measurements gave consistent results, the quenching or extinction limits being disturbed by the cooling of the side walls, this being essential, as the walls were in contact with the flame. The second series of tests, with bodies having a width of only 80 mm, so as to have a clearance of 10 mm on each side, showed an edge effect which was not negligible, but, as a whole, the measurements were consistent.

The obstacles were fixed to the lateral walls at their outer ends; the base pressure was indicated by means of a tube of 2 mm o.d. situated along the axis of the chamber, the tube being welded to the obstacle, with an orifice of 0·5 mm at the centre of its downstream face. This tube was connected to a transverse strut situated 200 mm upstream from the obstacle. The base pressure was transmitted to a differential manometer, of which the second branch was connected to a static-pressure tapping on the upstream side.

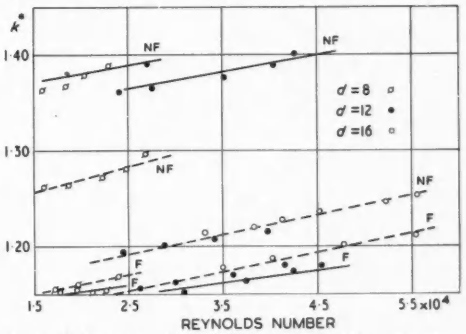


Fig. 4. Limiting values of base-pressure parameter k^* as a function of Reynolds number for cylinders.
Solid lines : $L = 100$ mm.
(F) With flame. (NF) Without flame.

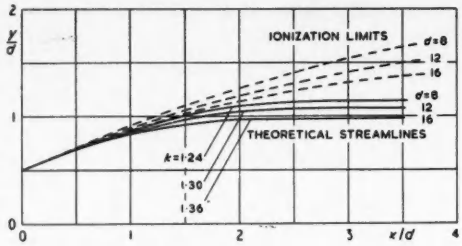


Fig. 5. Shape of wake for a flat plate in non-dimensional co-ordinates.

The influence of combustion on the wake is shown in Fig. 3, an air/fuel ratio A/F of 20 being maintained in all combustion tests. These graphs show the variation of the base-pressure, i.e., excess-velocity, parameter k as a function of the approach velocity V for the various bodies investigated. It is apparent that the pressure within the stabilized flame zone is higher than the base pressure of the obstacle without flame, and also that the velocity along the streamline increases with the transverse dimension of the obstacle, explaining the deficiency of the simplified correlation formulae. It is fairly difficult to estimate the effect of the end portions exactly, but it can be noted that the parameter k is always smaller for obstacles with a width L of 80 mm than for those touching the walls, i.e., with a width L of 100 mm. When k is corrected by a coefficient $(1 - s/\sigma)$, where s is the effective area of the obstacle and σ the section of the chamber, the limiting values of the parameter k^* thus obtained can be plotted against Reynolds numbers Vd/ν, as, for instance, in Fig. 4, which refers to the results obtained with cylinders. In this way the experimental results reveal a more consistent pattern.

The shape of the wake is indicated by the curves in Fig. 5, which give the external contours of flames stabilized on three flat plates of different heights, as determined by means of ionization probes[10]. For comparison, the streamlines evaluated from the base-pressure indications by Roshko's method are also indicated. Although non-dimensional co-ordinates x/d and y/d are used (d = obstacle diameter), the streamlines for three similar obstacles of different heights do not coincide, owing to the obstruction effects on the stream. This is also the case with the flame contours. The difference between the streamline and the flame contour is representative of the thickness of the flame itself. The asymptotic value of the interval between the streamlines has been chosen to characterize the width of the flame zone.

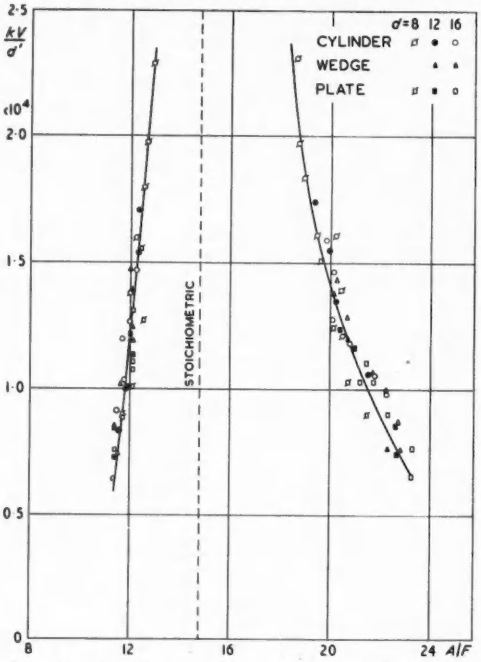


Fig. 6. Correlation between experimental results and extinction limits.

Extinction limits were determined only for obstacles of width $L = 80$ mm and the test points corresponding to the three main types of obstacles were plotted again on a single diagram, with A/F values as a function of the expression kV/d' (Fig. 6). All the points are situated close to the two branches of a single curve for the quenching or extinction limit. In plotting this diagram, the k-values employed were those recorded at the time of extinction, but the use of the k-parameters determined for $A/F = 20$, for example, would not have resulted in much greater scatter.

Conclusion

By means of the relations for the base-pressure parameter k and the wake width d', a correlation with very little scatter is obtained for the extinction limits of flames stabilized on obstacles of considerably different shapes. It is possible to evaluate correctly the velocity on the separation line of the wake from base-pressure values which are easily measured.

In the design of combustion chambers, it is possible to evaluate the k-values required for estimated performance figures on the basis of available lists of k^*-values and previous experience. In model tests, it is possible to measure base pressures for increased data on operating limits.

Obviously, some of these results may be generalized to apply to three-dimensional obstacles of any shape; the velocity along a streamline can also be related to the base pressure by the same formula, but it is then no longer possible to predict the shape of the corresponding flame.

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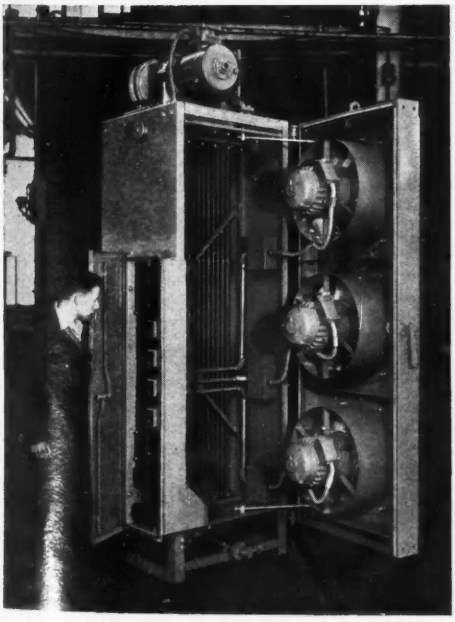
British Industrial Developments

Forced-Oil Air-Blast Cooler for Transformers

Intended for directly mounting onto a transformer tank end or side, a prototype forced-oil air-blast cooler developed by The British Thomson-Houston Co. Ltd., of Rugby, offers a considerable saving in space, compared with conventional side-mounted radiators. Furthermore, it has the advantage that it should be possible in many instances to despatch a complete factory-assembled unit comprising transformer and cooler, thereby reducing erection work on site. The cooler is designed to dissipate 100 kW with a maximum temperature rise of 40°C above ambient ; hence, a single unit will be suitable for transformer ratings up to approximately 15 MVA, while two or more cooler units in parallel can be used for larger transformers.

The cooler consists essentially of a sheet-steel cubicle containing the cooling elements (made of non-ferrous metal and not subject to rust) and a hinged door (shown open in the illustration) which carries three fans, the design of which has been given special attention to reduce windage noise. The control gear is housed in a compartment built into the main cubicle. The prototype equipment has been designed with two-speed fans and a single-speed oil pump driven by an oil-immersed BTH motor. The two-speed motors enable a dual cooler rating of 70 kW and 100 kW to be achieved, and at these ratings the total power inputs to the cooler motors are approximately 3 kW and 5 kW respectively. Further developments envisaged include the use of a change-pole oil-immersed pump motor which will give dual cooler ratings of 50 kW and 100 kW, with total power inputs of 1½ kW and 5 kW respectively. In practice, this dual rating feature will enable the fan motors to run continuously at half-speed when the transformer is lightly loaded, and it is believed that the motors will then prove even more reliable than in the conventional on/off cooling arrangement where fan motors are likely to stand idle, cold, and subject to condensation during severe weather conditions.



The equipment is complete with its own control contactors, overload relays, fuses, etc., each fan motor being separately protected, so that, should one fan motor be out of service, the operation of the other two is unaffected. Experience has shown that the oil-immersed pump motor is so reliable that it is unnecessary for the oil circulatory system to be subdivided. If two or more cooler equipments are fitted to a transformer, the control devices can be conveniently grouped, if desired, in a common control cabinet, together with other auxiliary services.

Special Lubricants for Nuclear Power Stations

A range of radiation-resistant lubricating and hydraulic oils and greases, to meet the current and future requirements of nuclear power stations, is announced by The Shell Petroleum Company Limited, of London, W.C.2. In this connection, Shell has been actively engaged in a considerable research programme at their Thornton Research Centre, where a special radiation laboratory, using a cobalt-60 source to provide intensive gamma radiation, has been built. This research work has been planned to obtain information on the influence of the molecular constitution of stability towards atomic radiations, and already lubricants have been developed which show practically no change in physical properties at radiation dosages which transform many lubricants into solids. In this connection, a very large number of materials, including a variety of synthetic and petroleum lubricants, has now been exposed to various dosages both of gamma radiation and neutrons.

As a result of this research work, Shell have developed a number of special lubricants which are resistant to radiation and which meet the requirements of the nuclear power stations now being built by the Central Electricity Authority. These lubricants, under the brand name of Shell A.P.L. (Atomic Power Lubricants), have already been chosen for use in the Bradwell station of the C.E.A. Further research is continuing, to develop lubricants even more resistant to radiation, such as will eventually be required for more advanced designs of nuclear power stations, and it is stated that promising results are already being obtained.

Wire with Irradiated Modified Polythene Dielectric

A new equipment wire, designated " Merad ", incorporating an irradiated modified polythene dielectric for use under conditions of higher than normal temperatures, has been introduced by Mersey Cable Works Limited, of Liverpool. The manufacture of this material follows a long period of investigation at the T.I. Group's Research Laboratories at Hinxton Hall into the effects of high-energy radiation on the physical and electrical properties of polythene dielectrics, various formulations of normal polythene and chemical modifying agents being exposed to high-velocity electron bombardment by a Van de Graaff 2-MeV particle accelerator.

By virtue of the high-temperature properties of this irradiated material, numerous important applications of " Merad " are possible. Thus, for instance, soldering can be effected right down to the insulation, and irradiated polythene cable may now be used for applications where

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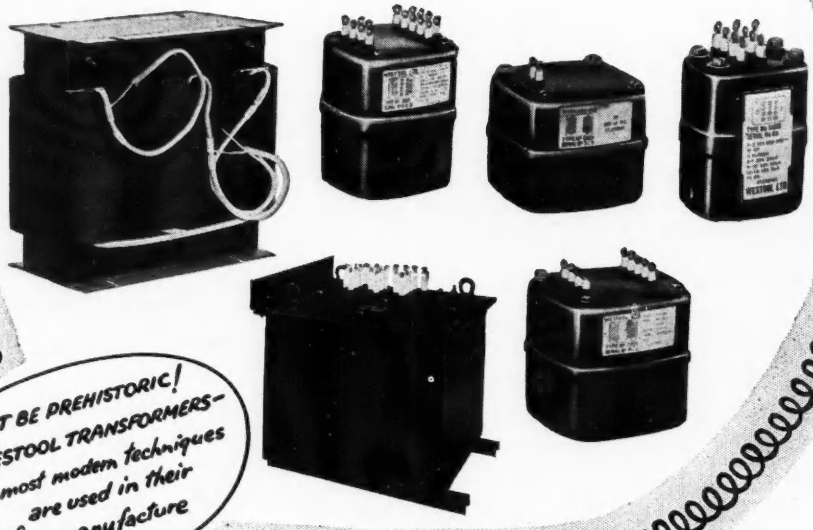

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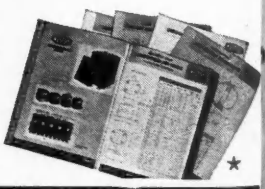

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high external temperatures are experienced. In addition, momentary overloads, which were formerly responsible for damaging or destroying the insulation, are rendered harmless since, unlike conventional polythene, " Merad " does not melt when exposed to higher temperatures, but is converted to a rubber-like substance which retains some useful strength up to a temperature of 450°C. Similarly, other physical properties of the material are either improved or unimpaired, the irradiated product being free from stress cracking in the presence of detergents, while resistance to the action of aromatic and aliphatic hydrocarbons is increased. In addition, tensile strength, elongation, and abrasion resistance are improved, while handling and flexibility characteristics are virtually unchanged.

The new material also provides a valuable supplement to existing methods of sleeving and encapsulation. Extruded sleeving with an inside diameter of $\frac{1}{8}$ in. can, when irradiated, be cold-distorted to an inside diameter of 0·2 in. or more to fit over terminals or components. After momentary reheating to between 135 and 150°C, it attempts to return to its original $\frac{1}{8}$ in. i.d., and thus encapsulates the component or terminal.

The manufacturing process at present is still in its infancy and is applicable mainly to limited quantities of certain types of insulated wires and small cables. However, the use of larger, more powerful accelerators, capable of deeper penetration of the material, may well see its extension to larger cables and electrical components generally. Other important implications of the process lie in fields apart from those of wire and cable insulation, for it appears that the effects of irradiation are not confined to polythene or other materials used for electric cable insulation. Important research into the application of the process to other substances is now in progress.

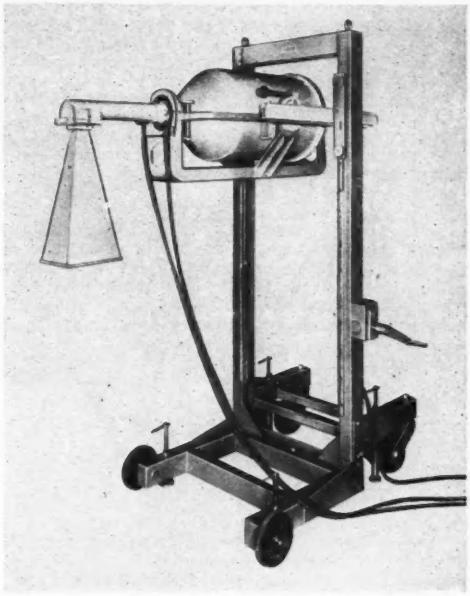
Gas-Insulated Industrial X-Ray Equipment

Designed to meet the demand for a lightweight radiographic unit suitable for use in factories or on open erection sites, the " Raymax 150 ", announced by Metropolitan-Vickers Electrical Co. Ltd., of Trafford Park, Manchester, is the latest addition to the Newton Victor range of industrial X-ray equipment. In this unit, which is the first gas-insulated X-ray equipment designed and produced in Great Britain, the use of a non-toxic inert gas (sulphur hexafluoride) as the insulating medium, together with the absence of high-voltage cables and rectifying valves, has resulted in a design of low weight and exceptionally rugged construction.

The equipment comprises a tube-head, a gantry stand, a control unit, and a cooling unit. The tube-head consists of a high-voltage transformer, a filament transformer, and the X-ray tube, all housed in a cylindrical steel tank, 18 in. in diameter and 36 in. in length, filled with sulphur hexafluoride at a pressure of 20 psi, the breakdown value of this gas being similar to that of oil, but with the advantage of being less easily contaminated. As thermal changes do not increase the volume, an expansion tank is unnecessary and, because the gas pressure is so low, simple means can be adopted for filling the tank and for changing the X-ray tube.

Two types of X-ray tube are available, i.e., the NVI.400 and the NVI.450. The NVI.400 tube, with its 20-deg. target, giving a cone of radiation with a half angle of 15 deg., and its fine focus, makes it ideal for the general radiography of welded joints, light-alloy castings, etc. The NVI.450 tube is generally similar in construction to the NVI.400, but the anode is at 90 deg. to the electron beam, and the window provides a 360-deg. beam of radiation for examination of circumferential welds, hollow castings, and small specimens arranged in a circle.

The gantry stand provides a versatile support for the tube-head, with a vertical travel of 48 in. Pivots on the



long and short tube-head axes permit the beam to be angled in all directions. The horizontal traverse of the tube-head is 16 in. Castoring wheels are fitted at the rear, and fixed wheels, turning through 90 deg., at the front. For special work the tube-head and cradle can be easily removed from the stand.

The small portable control unit has been designed for wall or desk mounting in permanent installations and is of a convenient shape and size for site work. The continuously adjustable tube voltage has a range from 50 to 150 kVp, sufficient for all light-alloy castings, plastic mouldings, or assemblies, and for welded steel plate up to $1\frac{1}{2}$ in. thick. The kilovoltmeter is calibrated to read the peak voltage applied to the X-ray tube at a current of 10 mA, and a milliammeter indicates the tube current ; both instruments can be covered by a steel shield when not in use. The synchronous-motor exposure timer has a range of 1 sec to 55 min in steps of 1 sec. Indicating lights are provided to show closure of the main switch, adequate water supply, and high voltage applied to the tube.

A motor-driven pump circulates water continuously through the anode of the X-ray tube and through a fan-cooled radiator. High- and low-pressure relays prevent, or interrupt, operation of the equipment, should the water flow be insufficient to cool the target of the tube efficiently. Mains water, where available with sufficient purity, may be used to cool the tube, and relays are then provided to ensure the requisite flow of water during operation.

Multi-Station Automatic Lubricators

Suitable for use on all types of mechanically operated equipment, including machine tools, printing machines, and fabric machines, the new " Electromatic " gravity-feed multi-station automatic lubricators announced by A. A. Jones & Shipman Ltd., of Leicester, employ an entirely new principle, working quite independently of the machines to which they are fitted, and permitting oil discharge to be determined at will, irrespective of the diameter, speed, or construction of the machine.

These lubricators, which are operated by a small geared synchronous motor, eliminate any possibility of localized action, the oil being discharged and conveyed to any

cut out that operation!

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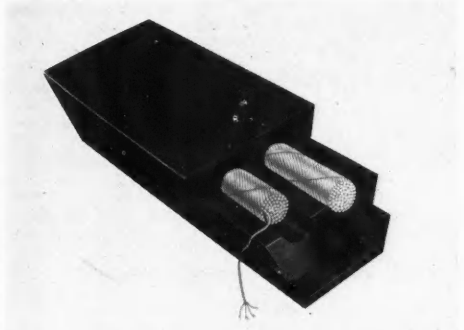
predetermined lubrication point via transparent plastic tubes. Furthermore, once installed, they require practically no attention, their moving parts being constantly submerged in oil and subjected to very little wear. The oil container is of adequate dimensions and holds sufficient oil for about 200 hr under normal factory conditions.

Three types are available, i.e., for 4, 6, or 16 stations. Time frequency between oil deliveries of each station can be set for from 30 sec upwards. On the types of machine for which they are intended, full use can be found for the large number of feeds available, permitting oil to be conveyed to a number of places which often are normally almost inaccessible to operators.

V-Belts with Grommet Construction

The introduction of " grommet " construction in their range of high-test V-belts, with the consequent advantage of improved performance and efficiency, is announced by the British Tyre & Rubber Co. Ltd., of London, S.W.1. The grommet comprises an endless spirally wound rope-like structure made from high-tensile rayon cord, and the new BTR V-belts incorporate two such units symmetrically spaced on the pitch line of the belt and completely surrounded by a cushion of resilient and heat-dissipating rubber. The outer cover consists of a double ply of rubber-impregnated fabric specially designed and woven to provide maximum abrasion resistance and high frictional grip on the driving faces of the pulley.



One of the most important advantages of the grommet construction is that, notwithstanding its greater strength, it is extremely supple. This means that the grommet absorbs less energy and creates less internal heat when flexing round the pulley than conventional cord or fabric reinforcement. Furthermore, the spirally wound construction of the new tensile members ensures that each thread bears an equal share of the load (a vital factor in V-belt performance) and, as there is no ply-upon-ply of fabric reinforcement to stiffen the belt, there is a reduction in bending losses and an increase in flex life, with less stretch and reduced maintenance costs.

Analogue Computer For Cable Problems

An analogue computer designed for application to heat-transfer problems in electrical cables has been added to the range of quality-control and automation equipment for the cable industry produced by the Addison Electric Company Limited, of London, W.10. Stated to be the first commercial computer available for this specific purpose, the new instrument permits the determination of the temperature rise at given times and at various locations inside and outside the cable upon the application of a prescribed load cycle, eliminating time-consuming calculations of great complexity.

The principal uses of the new computer, which is mainly intended for engineering offices and combines portability, relative simplicity, and low cost, may be summarized as follows :

(1) Determination of short-time emergency ratings and the percentage of ultimate temperature rise after a given time with constant loads for various cable systems.

(2) Determination of the effect of load and maximum temperature rise occurring during a given cyclically applied loss cycle in various cable systems.

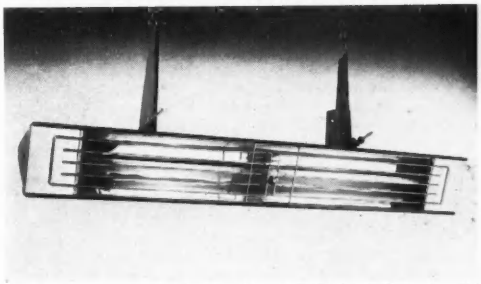
(3) Determination of oil-flow problems and the temperature rise at various points in various cable systems as a function of time.

In use, the thermal constants of the cable and its surroundings are represented by the electrical constants of a resistance-capacitance network. These are set up by means of front panel controls, together with the required load conditions, which can be in the form of a complete 24-hr load cycle. The thermal behaviour is then studied at preselected points and times by the aid of a valve voltmeter, whereby 1 hr of actual time normally corresponds to 1 sec of computing time.

Radiant-Heating Units

A range of radiant-heating units, designed and constructed by Société Quartz & Silice, of Paris, is now being manufactured under licence by Unidare Ltd., of Dublin, Eire, and is marketed in the U.K. by their subsidiary company, Thermodare (Great Britain), of London, S.W.1. In these units, a high-temperature heating element, mounted in a silica tube, itself emits radiant-heat energy at a wave-length of approximately 2 microns but, in passing through the silica tube, some of this infra-red energy is absorbed by the tube and is re-radiated at a longer wave-length. This results in a broadening of the spectrum on the longer wave-length side and produces a more uniform radiation between 2 and 4 microns.

Since a thin film of water has a very high absorption at 3 microns, this method of heating is particularly suitable for industrial drying processes and, as other liquids are similarly effected, it is specially indicated for paint-drying and stove-enamelling operations, resulting in a considerable saving in drying time and production costs. Operating on a wave-length of 3 microns, an efficiency of the order of 93% is obtained, and the silica tube can safely be subjected to water spray during operation.



At the moment, three units, each 32 in. in length, with interchangeable elements of 800, 1200, and 2000 W, are available, but these will be followed by a smaller 100-W unit and by two large 53-in. units, of 3000 and 4000 W. The effective angle of radiation is 60 deg. in both planes ; the 2-kW model has a throw of 20 ft, that of the other models being in proportion to their power. The reflector is constructed of pure polished aluminium, the remainder of the unit being of steel. Two simple screwed rods enable the angle of the unit to be adjusted to the correct angle.

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ADDITIONAL ABSTRACTS

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Losses at the Contact Surfaces in Friction-Type Variable-Speed Gears.

By V. A. MIKHAILOVA and D. N. RESHETOV. (From *Vestnik Mashinostroyeniya, Russia*, No. 2, February 1957, pp. 8–18, 10 illustrations.)

IN this paper, an analysis is given of the distribution of sliding over the contact surfaces of the rolling bodies in friction-type infinitely variable speed gears. The point of pure rolling is determined, and the cones tangential to the actual contact surfaces are established, leading to a distribution of sliding velocities over the Hertz contact-pressure ellipse. A graph facilitates finding the point of pure rolling from the factor relating the actual torque to the maximum friction torque, the major and minor axes of the contact pressure ellipse, and a geometric relation between the tangent cones. The slip coefficient expresses the deviation of the actual from the ideal speed ratio, and graphs and nomographic charts are reproduced to determine this coefficient.

A chart shows nine mechanisms used in variable-speed transmissions, each with its equation for computing the true speed ratio. The more prominent friction mechanisms have slip plotted against speed ratio and output speed, the analysis of slip being rearranged to yield the mechanical efficiency of the gear. The efficiency so determined embraces only those losses due to sliding over the contact area, but these form a substantial proportion of the total losses. It is claimed that gears based on the toroidal cone-and-ball principle have the lowest slip losses, the next best having losses 2½ times greater, rising to 11 times in the double-disc and sliding-roller types. The effect of speed range is substantial. In the toroidal cone-and-ball type, slip losses increase by a factor of 3·2 when the range increases from 2 to 6, and by a factor of 6 when the range reaches 10. Maximum hardness of the contact surfaces is essential.

Improved Adherometer using an Electronic Averaging Device.

By A. G. ROBERTS and R. S. PIZER. (From *ASTM Bulletin*, No. 221, April 1957, pp. 53–58, 6 illustrations.)

BECAUSE of the great importance of good adhesion in the service performance of protective coatings, much effort has been directed, with only partial success, towards the development of test methods which would permit laboratory evaluation of the adhesion property. Previous work with the adherometer has indicated that the reliability of results would be considerably improved if the variable stripping force encountered could be averaged by some means. It has been suggested that this might be accomplished by translating the variable stripping force into a variation in an electronic circuit whose output would actuate a standard recorder to give a graph from which the average value of the stripping force could then be obtained.

This paper describes equipment which not only translates the variable adherometer stripping force into electrical impulses but also sums these varying impulses to give a single average value which can be read directly either from a voltmeter or a standard recorder. The speed and reliability of adherometer measurements have thus been significantly improved.

In this improved adherometer, the pendulum conventionally employed as a source of the stripping force needed at the cutting head is replaced with a beam and strain gauge assembly whose output is fed to a specially designed electronic integrating device, yielding an average value of the variable stripping force usually encountered. The output can be read on a voltmeter or fed to a conventional recorder, and voltages or chart readings are converted to force values by reference to a calibration curve.

Precise timing of the stripping run and the various electronic switching operations entering into the integration process are performed automatically. The strain and error involved in the visual observation of varying gauge readings are eliminated. The stripping action itself is accomplished with greater ease and uniformity because of the great reduction in the momentum and inertia effects associated with the pendulum method. The upper limit of available stripping force is more than twice that of the conventional adherometer.

Tests with eleven different coatings yielded an average coefficient of variation of 4·1% for the pendulum method and 2·2% for the new method. Thus, the conventional adherometer, even under the highly favourable averaging procedures employed, here exhibited a variability significantly greater than that of the new method. With more highly variable coating systems, the precision of the conventional adherometer would be expected to suffer accordingly, whereas the precision of the new method would remain essentially unchanged.

Thermodynamic Study of the Number and Positioning of the Feed Pumps in the Feed Train of a Regenerative Steam Cycle.

By R. W. HAYWOOD. (From an advance copy of a paper submitted to *The Institution of Mechanical Engineers, London*, May 1957, 7 pages, 3 illustrations.)

IN this paper, an approximate method of analysis is developed to compare the performance of single-pump and split-pump schemes in the non-reheat regenerative steam cycle. The study reveals that cycle efficiency is slightly better for the split-pump arrangement. Although this advantage is so small as to be practically negligible, it is reinforced by other advantages of a practical and economic nature. A practical advantage is the fact that, with the split-pump arrangement, not all the heaters are subjected to full boiler pressure.

A point in favour of the single-pump scheme is the provision of only one pump, with an input smaller than the combined inputs of the two pumps in the split-pump scheme. However, it has been estimated that, for 120-MW units, although the single pump and motor might cost some 30% less than the two pumps and motors in the split-pump arrangement, the cost of the heaters might be 50% higher when using a single pump, because the heaters would all be subjected to full boiler pressure ; consequently, the total expenditure would be considerably higher for the single-pump scheme. With the additional continuous small saving on fuel, the split-pump scheme is seen to be preferred on both counts.

Throughout the paper reference is made to the true final feed temperature at the boiler inlet. Only in terms of this temperature is the efficiency of a completely reversible cycle the same for all possible alternative arrangements which involve no irreversibilities. In spite of the fact that this is the only true final feed temperature, it has been customary, for obvious practical reasons, for makers' guarantees to be given in terms of the feed temperature at the exit from the last heater. If this temperature were kept the same for the two schemes, then the advantage would be still more in favour of the split-pump arrangement, because its true final feed

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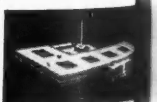

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temperature is greater than that of the single-pump scheme by an amount equal to the temperature rise in the high-pressure pump, which is of the order of 4°F for the conditions quoted. The additional gain in thermal efficiency consequent on the higher mean temperature of heat reception is quite artificial, however, since it results from a basis of comparison which is unscientific.

The Effect of Dissolved Oxygen on the Corrosion of Steel and on the Current Required for Cathodic Protection.
By E. SCHASCHL and G. A. MARSH. (From *Corrosion, U.S.A.* Vol. 13, No. 4, April 1957, pp. 35–43, 11 illustrations.)

DISSOLVED oxygen is recognized as playing an important part in the corrosion of steel. As a result of its function as an effective cathodic depolarizer, it controls the corrosion rate of steel in aqueous solutions, this corrosion rate being determined by the dissolved oxygen content available at the surface of the steel. Any factor affecting diffusion of oxygen will have a marked effect on corrosion rate.

The work described in this paper was undertaken to provide quantitative information concerning the relationship between dissolved oxygen concentration, corrosion rate, electrode potential, and minimum current required for cathodic protection. The systems studied were steel in synthetic laboratory electrolytes, it being felt that the data would be more readily interpreted in this way than if complex natural systems were used.

While the corrosion rate of steel is essentially linear with dissolved oxygen, it appears to fall almost to zero near 1·0 ppm, instead of at zero ppm dissolved oxygen, as commonly assumed. Therefore, it is not necessary to de-aerate completely in order to provide a low corrosion rate. In the region below 2 ppm dissolved oxygen, there is almost no effect of agitation on corrosion rate ; above 2 ppm, the effect is pronounced.

In neutral environments, the minimum current density needed for protection is about 20% greater than the current associated with corrosion. By measuring the corrosion rate of an unprotected specimen, it should be possible to compute the minimum current density needed for cathodic protection in the field.

In acidic environments, less current is needed for protection than is predicted by analysis of the mechanism of cathodic protection. This fact suggests that the anodic reaction in low-pH corrosion proceeds by the removal of "chunks" of metal which contain several atoms. The "chunk effect" also appears to operate in the neutral range, but only when the corrosion rate is very high.

Differential aeration is shown to be an important factor in corrosion if a structure is buried at the water table. In a static, liquid-saturated porous system, however, there is no appreciable effect of differential aeration, even when the bulk oxygen concentrations at the anodic and cathodic areas are widely different.

Measurement of Residual Stresses in Alloy-Steel Forgings.
By A. BARKER and E. H. HARDY. (From an advance copy of a paper submitted to *The Institution of Mechanical Engineers, London*, May 1957, 15 pages, 20 illustrations.)

THE importance of the residual stresses which arise in alloy-steel forgings from temperature differences set up during heat treatment and also from volume changes due to the austenite-ferrite transformation is now generally recognized. It is therefore necessary for metallurgists to control the magnitude and distribution of such stresses. The purpose of this paper is to examine the methods available for residual stress measurement in large forgings and, in particular, to describe the refinements in strain-gauge technique needed. Two methods are available, both dealing only with cases where the geometry and stress distribution are symmetrical about the same axis, and when the shape approximates to an infinitely long cylinder.

The first method involves trepanning a core of the material from the axis of the forging and estimating the mean residual stress in this from measurements of the difference between its length and that of the remainder of the forging, after the core has been removed. It is limited in its application, but can, in some cases, give longitudinal bore stresses to an accuracy better than 1 tsi. Also, it can often be carried out without destroying the forgings.

In the other method, due to Sachs, a long cylinder is bored out in stages and, after each stage, length and diameter changes are obtained, from which the distribution and magnitude of the three principal stresses can be obtained. It is not possible to estimate the probable error in simple terms, as this will vary from one type of stress distribution to another. In the case of forgings with low residual stresses of, say, 10 tsi, the error is likely to be of the order of 1 tsi in any position. At higher stress levels, particularly where plastic deformation can occur, somewhat greater errors may be present, and it is generally not possible to achieve an accuracy higher than 10% in these circumstances.

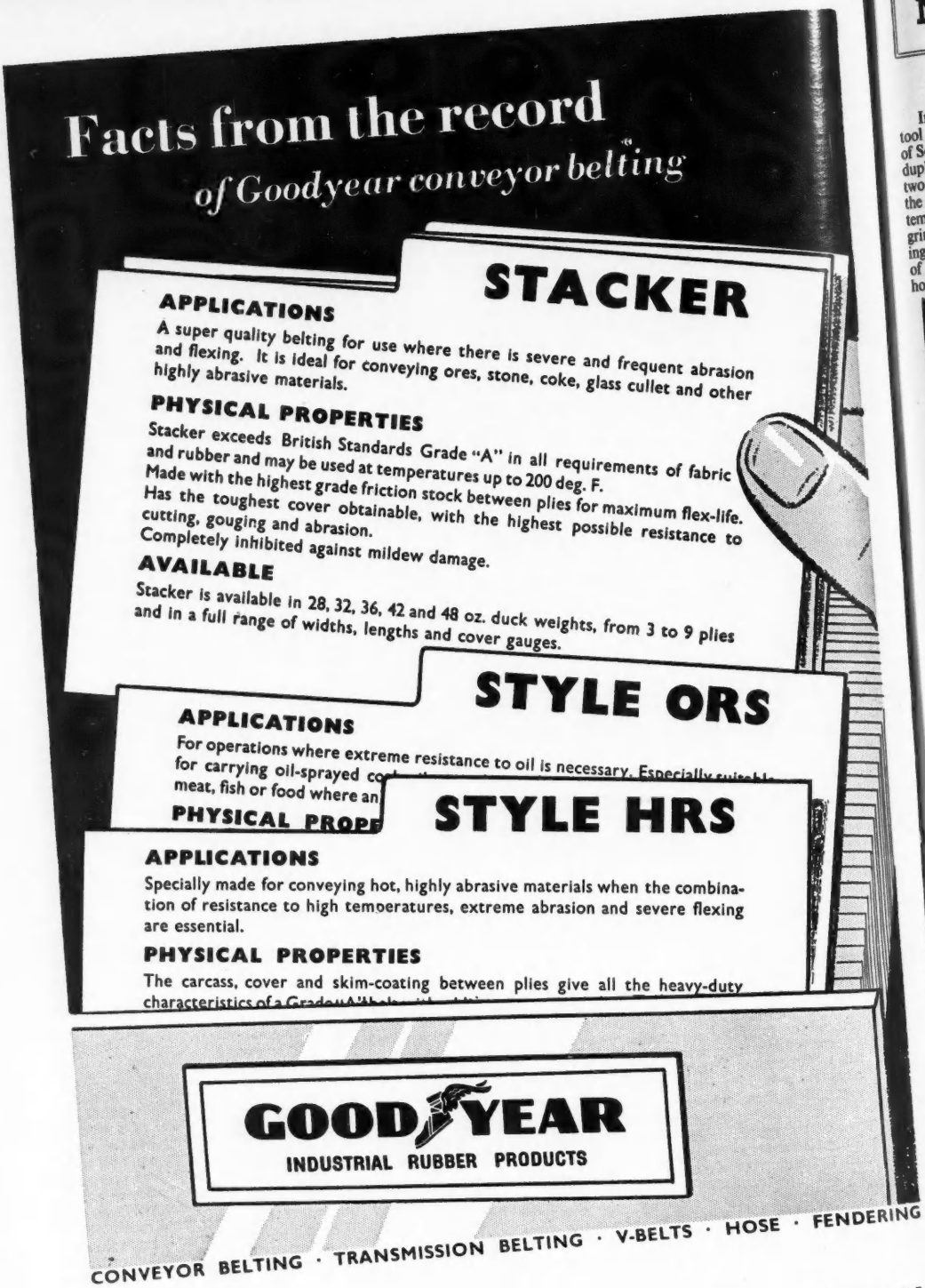
Speed Control of Induction Motors with Saturable Reactors.
By P. L. ALGER and Y. H. KU. (From *Power Apparatus and Systems* (*A.I.E.E.*), *U.S.A.*, February, 1957, pp. 1335–1341, 12 illustrations.)

THE speed of an induction motor can be maintained precisely at any desired value by placing saturable reactors in series with the motor windings and holding the direct current in the reactor at the appropriate value with a feedback control circuit. For small changes from full speed and when the torque required is relatively small, squirrel-cage motors may be used, with the reactors in the primary circuit. For large changes in speed and when high torques at low speed are required, wound-rotor motors with secondary resistors may be used, and the reactors may be located in either the primary or the secondary circuit. When braking or reversed-torque operation is required, two independent primary windings, with either the same or a different number of poles controlled by independent reactors, may be used.

With the progress in automation, there is a growing need for precise and stepless control of motor speeds in driving fans, pumps, conveyors, and all types of machines. Usually, d.c. motors with field and/or voltage control, or induction motors driving the load through eddy-current clutches, are employed for this purpose. In this paper, another method of induction-motor speed control is considered, employing feedback-controlled saturable reactors in series with the motor windings.

The performance of the reactor speed-control scheme is considered as a problem in power modulation, in which an electric energy source forms the input, and controlled torque and speed are the desired outputs. This method does not require a d.c. power supply, or any commutators or power tubes. In addition to an essentially standard induction motor, the scheme uses only readily available reactors and control circuits. The direct current required for the control is only 1 or 2% of the motor rating, and can readily be supplied from amplistats or equivalent devices, just as in the case of the clutch.

Calculated and test data are given, showing that this method of speed control allows the speed of a wound-rotor induction motor to be set at any desired value between 100% forward and 100% backward, and to be held nearly constant at the set value, over a full range of torque from plus (motoring) to minus (braking), up to the maximum torque value. This speed control is accomplished merely by turning a small control knob. This inherent ability to hold the desired speed, regardless of whether the load requires motoring or braking torque, makes the scheme especially suitable for bridges and hoists, and provides characteristics not attainable with eddy-current clutch drives.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Stacker exceeds British Standards Grade "A" in all requirements of fabric and rubber and may be used at temperatures up to 200 deg. F.
Made with the highest grade friction stock between plies for maximum flex-life.
Has the toughest cover obtainable, with the highest possible resistance to cutting, gouging and abrasion.
Completely inhibited against mildew damage.
AVAILABLE
Stacker is available in 28, 32, 36, 42 and 48 oz. duck weights, from 3 to 9 plies and in a full range of widths, lengths and cover gauges.
STYLE ORS
APPLICATIONS
For operations where extreme resistance to oil is necessary. Especially
for carrying oil-sprayed
meat, fish or food where an
PHYSICAL PROP
STYLE HRS
APPLICATIONS
Specially made for conveying hot, highly abrasive materials when the combination of resistance to high temperatures, extreme abrasion and severe flexing are essential.
PHYSICAL PROPERTIES
The carcass, cover and skim-coating between plies give all the heavy-duty
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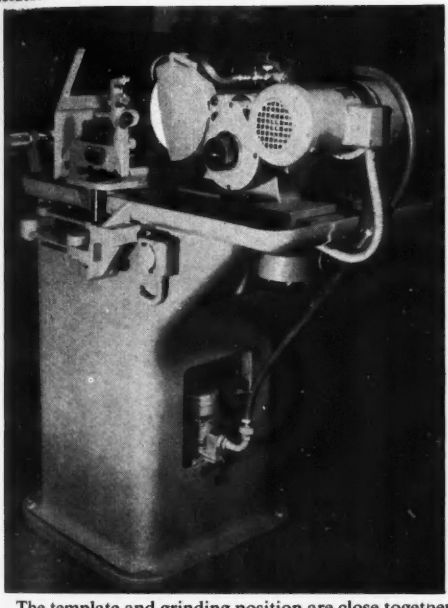
INDUSTRIAL RUBBER PRODUCTS
CONVEYOR BELTING · TRANSMISSION BELTING · V-BELTS · HOSE · FENDERING

New Materials, Processes, and Equipment

TEMPLATE-CONTROLLED TWIN TOOL GRINDING MACHINE

In the " Copyrex ", a new template-controlled twin-tool copy-grinding system, developed by F. Blasi & Co., of Solothurn, Switzerland, two identical, interchangeable duplicate-profile tools are ground simultaneously with two grinding wheels in the same operation. Grinding of the desired shape is effected in the copying process from a template enlarged to five times full size and, during grinding, the template is guided along a stationary copying finger, movements being transmitted with a reduction of 5 : 1 through a pantograph linkage to the tool-holder.



The template and grinding position are close togetner, so that they can be easily supervised during operation. Furthermore, the template can be guided without undue fatigue. The pantograph moves very easily, as it runs on precision ball bearings, while the grinding spindle requires no attention. Approach of the grinding wheels is effected by a handwheel with graduations of 0·0·004 in. For grinding circular lathe tools, form rollers, cylindrical production parts, etc., a cylindrical grinding attachment is available, mounted on a tilting plate, instead of on the tool support. This attachment is driven by a separate electric motor through a reduction gear.

The copying-finger holder is arranged to take three different fingers simultaneously, any one of which can be brought into contact with the template. These copying fingers are graded in shape and are interchangeable. For grinding simple shapes, it is possible to use only one finger. The same copying finger is adopted each time for truing and for copying.

In order that the workpieces may receive the exact intended profile, the wheel must correspond to the shape of the copying finger in the ratio of 1 : 5. For truing the grinding wheels, the three-point truing template is brought into action, instead of the copying template, simply by turning the handle. As soon as the copying finger is contacted by the truing template, the grinding wheels receive positively, through three diamonds, the exactly similar, reduced profile. The change-over can be made quickly, since the diamond holders are hinged. The copying template is normally made of easily machined sheet-aluminium or brass, $\frac{1}{8}$ in. thick. It is even possible to make very complicated shapes of templates with very high accuracy, since these are five times full size.

The inclined position of the tool to be ground—a position essential for attaining the clearance angle—would cause distortion of the profile. For turning the workpieces, the template is tilted, thereby automatically correcting the profile. No graphic determination of distortion, or the use of any specially distorted template or mathematical corrections, is required.

HYDRAULIC HIGH-SPEED DYNAMOMETER FOR GAS TURBINES

Stated to be able to absorb up to 3000 shp continuously at 7000 rpm, and capable of operation at even higher speeds, a new high-speed, high-power-absorption device, the " Hydra-Brake " hydraulic dynamometer, model WWX-650, is announced by the Industrial Engineering Company, of Philadelphia, Penn. Strain gauges, mounted on the torque shaft transmitting power from an engine to the Hydra-Brake, measure and report engine torque. These torque data, together with shaft-speed measurements, can be used to determine engine performance.

Basically the dynamometer comprises a hydraulic cylinder with rotor and stator discs, and water at a constant input pressure is forced through the cylinder. The unit is mounted on a torque shaft which is, in turn, connected to the engine shaft, power being absorbed by a combination of a pumping and shearing action, with acceleration and deceleration of the water as it passes through the unit. The Hydra-Brake is only 12 in. in diameter by 20 in. in length, and weighs less than 300 lb., occupying about 25% of the space and less than 2% of the weight required by a comparable electric dynamometer capable of handling the equivalent horsepower-speed range. Furthermore, compared with an electric dynamometer, which normally requires permanent installation in a test cell, the Hydra-Brake, torque shaft, and gas turbine can be mounted and aligned as an integral unit in the assembly area and subsequently sent complete to the test cell. Finally, the total cost of the Hydra-Brake installation is stated to be about one-third of that of an electric dynamometer of comparable capacity.

NUCLEONIC CONTROL SWITCH

The " GammaSwitch ", announced by Isotope Developments Ltd., of Reading, Berks., is an interesting development in the application of nucleonics to the control of industrial processes, and is believed to be the first inexpensive general-purpose industrial device to be based on radiation detection. Examples of the type of control which can be achieved very simply and reliably by this switch include level control, density and liquid-interface detection, and detection of flow failure. Furthermore, this technique has several advantages, compared with non-nucleonic methods; thus, for example, no probes, floats, electrodes, or other electrical or mechanical connections are needed inside the hopper, tank, pipe, etc., the device being mounted entirely externally. Furthermore, it is not necessary to drill holes through the vessel to which the switch is attached, and, when desired, it can be mounted independently, to avoid the effects of heat, vibration, etc., transferred from the vessel.

The device, which is essentially a switch and not a

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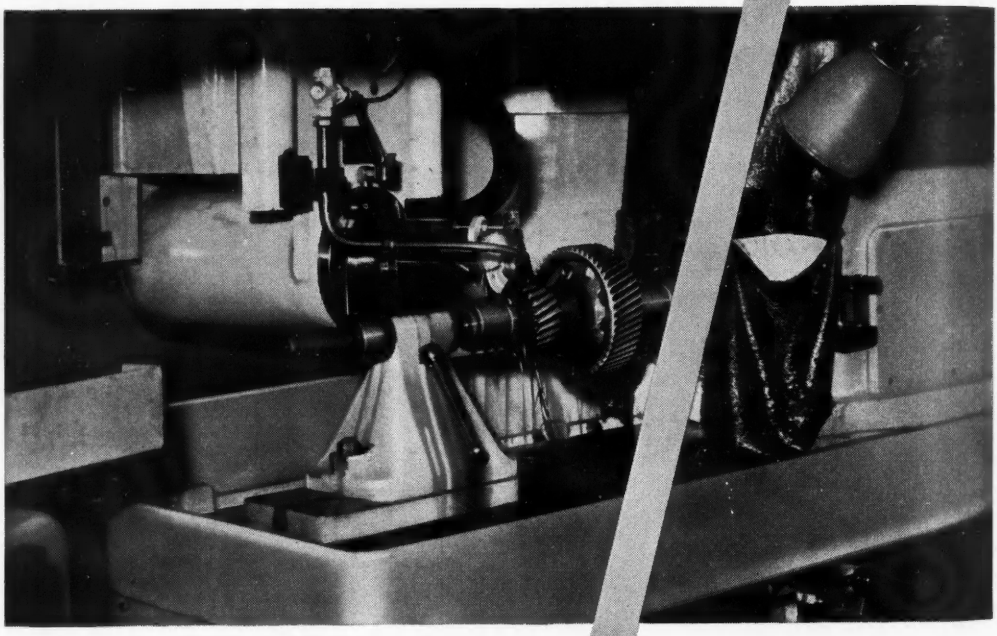
and the ROLLS-ROYCE *Dart 510*



Orcutt H.K.N. External Helical Gear Grinding machine grinding low-speed teeth of Dart 510 propeller turbine layshaft at Derby with "Ilocut".

"Ilocut" is Wakefield-Dick's best-known range of neat cutting oils. Its high quality never varies — and it is specified by a number of this country's leading production engineers. Rolls-Royce Ltd. use "Ilocut" and many other of our production oils in their Aero Engine Division at Derby in addition to their Crewe, Barnoldswick and Glasgow works.

INDUSTRIAL WAKEFIELD-DICK LUBRICANTS

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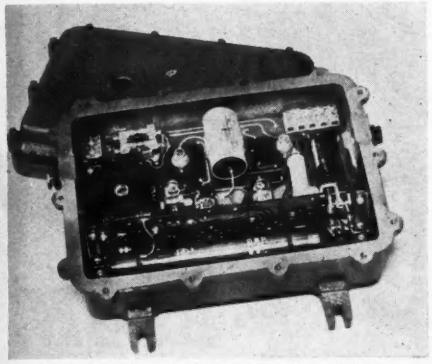
precision measuring instrument, consists of a halogen-quenched Geiger-Müller tube in circuit with a simple relay, built onto a printed-circuit chassis and contained in a fireproof or weatherproof cast-alloy base measuring approximately 11 × 10 × 4 in. The switch is connected to a normal mains supply, and its relay contacts can be wired directly into conventional control circuits, the relay operating when a predetermined intensity of gamma radiation is detected by the Geiger-Müller tube.



An example of a suitable application of the Gamma-Switch is the control of high and low level of material in a hopper. In this case, the switch is mounted at the appropriate level outside the hopper, and a gamma-ray source, suitably enclosed, is mounted on the opposite side. If the relay is set to trip when the radiation penetrating the hopper changes by the amount absorbed by the material, a warning light or audible signal can be operated by the switch whenever the material passes the predetermined level. Alternatively, the switch can be connected to the device controlling the supply of material to the hopper, thus providing automatic control. Similarly, the switch and detector can be mounted on each side of a conveyor, so as to give warning of a failure in supply of the material, or it may be installed on a pipeline to signal any appreciable change in density of the fluid passing through. When employed in key points in such installations, the switch greatly facilitates mechanization and automatic control and, as its mechanism is completely protected from abrasion and other mechanical damage, very little maintenance is required.

PHOTO-TRANSISTOR RELAY

Intended to replace mechanical limit switches in applications where it is not permissible to touch the initiator and where the speed of operation of a mechanical switch may lead to wear and failure, the new " Magistor " photo-transistor relay introduced by Metropolitan-Vickers Electrical Co. Ltd., of Trafford Park, Manchester, dispenses with the need for thermionic valves, large photo-electric cells, and high-tension supplies. Typical applications include counting, warning devices, level control, height gauges, door control, smoke detection, inspection, sequence checking, and sorting.

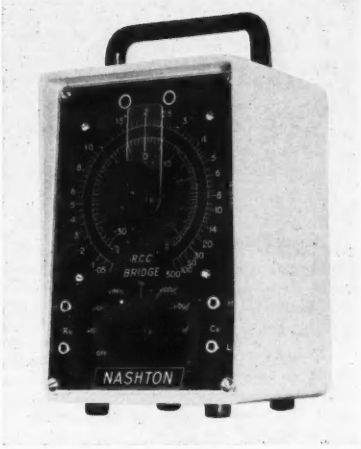
The equipment consists of two small units, i.e., a lamp-box and a receiver. The lamp-box contains a transformer supplying a prefocused lamp, the light from which is directed through a lens which produces a parallel beam to the receiver unit, where it is focused by another lens onto a photo-transistor. The output of the photo-transistor energizes a flux-resetting transducer, which controls a relay fitted with change-over contacts.

The photo-transistor used is a germanium-junction transistor, which is light-sensitive and has the advantage of small size ($\frac{1}{4}$ in. in diameter by $\frac{1}{2}$ in. in length). The flux-resetting transducer is simply a choke wound on a core of special material, the impedance of which can be varied by the action of the applied voltage during the reverse half-cycle, so that it responds to applied signals in approximately 0·01 sec on a 50-cps supply. The circuit is so arranged that the transducer has a very high impedance when light falls on the photo-transistor, and a very low impedance when the beam is interrupted. The transducer is connected in series with the relay coil and acts in the same way as a magnetic switch, closing the circuit and energizing the relay whenever the light beam is cut off. Interconnections between the two units are limited to only two wires, and the combination of a simple circuit with printed wiring ensures reliability. The relay, which has a total power consumption of 16 W, can, if desired, be supplied with electrical counters for speeds up to 10 per second.

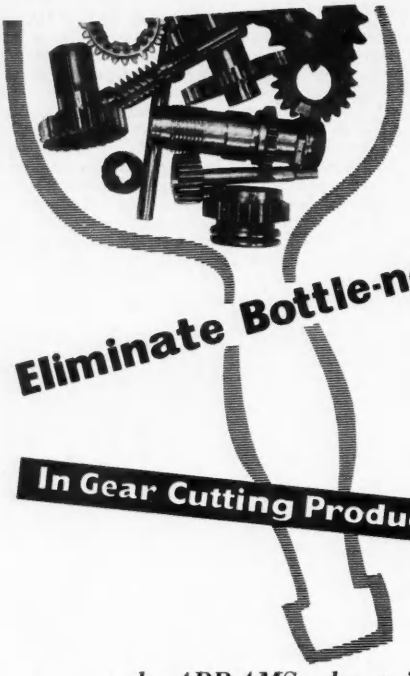
RESISTANCE-CAPACITANCE COMPARISON BRIDGE

Intended for the measurement of resistance and capacitance, or for the comparison of resistors, capacitors, or inductors against known standards, the new " Nashton " resistance-capacitance comparison bridge announced by Nash and Thompson Limited, of Chessington, Surrey, employs the principle of the Wheatstone bridge in resistance measurement and comparison, and the de Sauty bridge in capacitor measurement and comparison. In both instances, measurements are made at mains frequency with an applied potential of 18 V.

Both bridge circuits are rendered extremely sensitive by virtue of the novel twin neon device used to indicate the balance point. This consists of two small neon lamps, visible through circular apertures at the top of the panel. To obtain a reading, the balancing potentiometer carrying the scale cursor is rotated clockwise or anti-clockwise in the direction of the lighted neon lamp. As the cursor approaches the value of the component under test, this lamp will dim until, at the final balance point, it goes out altogether. On passing through this point the other neon lamp will ignite, and it is possible to pinpoint the true value of the component extremely accurately by adjusting the cursor position until both indicators are either completely extinguished or just glowing equally.



The incorporation of this indicator and the use of high-quality, high-stability components afford a degree of accuracy and reliability not often found in bridges of this type and size. The balancing potentiometer is wire-wound and cam-corrected, and has a guaranteed linearity of within 0·1%, permitting the use of a pre-printed metal scale on the panel, practically incapable of damage. As no sensitive meter is incorporated, and as there is only one vacuum tube in the circuit, the instrument is virtually insensitive to mishandling.



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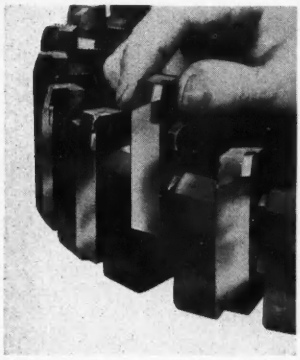
MILLING CUTTER

Eliminating conventional cutter grinding, the new "Abul" milling cutter announced by Harry Milnes Ltd., of Sheffield, can be set rapidly in progression or in line, using the same body and tools, the body being designed to take tools for light alloys, cast iron, and steel.

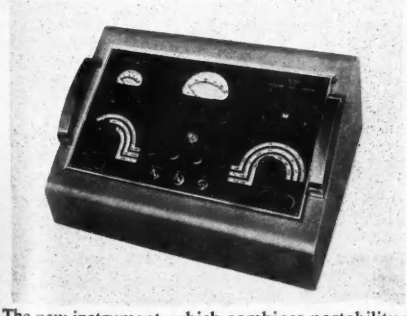


To set the cutter for progression, the first tool is set in the serration at a maximum distance from the centre of the cutter body, with the height of the tool approximately $\frac{3}{8}$ in. from the body face. Progressive tools are set one serration nearer to the centre, and the height of the tool is governed by the depth of cut required. Tools are set in line by placing the first tool in the body with the point of intersection of the tool approximately in line with the outside diameter of the cutter body, and with the height about $\frac{3}{8}$ in. from the face, and then setting the remaining tools in the corresponding serration in all slots, clocking each tool to maintain height.

To facilitate regrinding of the tools, fixtures have been made which can be fitted to any standard free-hand diamond-lapping machine, the oscillating-table type of lapping machine being preferable. These fixtures ensure that all tools are lapped and that, when finished, they are identical with each other.

PORTABLE TRANSISTOR TESTER

Complete information on the characteristics of a junction transistor can be obtained only at the expense of a long series of measurements with relatively complex apparatus. However, where such complete information is not essential, the new model L.264 transistor tester announced by Mullard Ltd., of London, W.C.1, provides a useful indication of the state and general characteristics of a transistor in much the same way as a conventional valve tester.

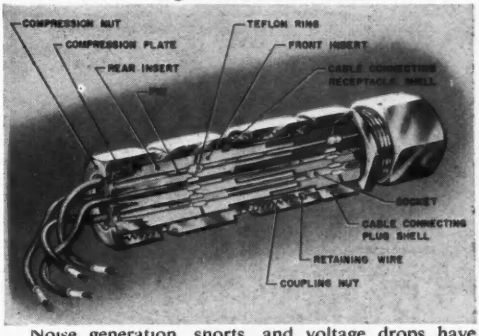


The new instrument, which combines portability with accuracy, is extremely simple to operate, and caters for the measurement of base-collector short-circuit current, d.c. collector current for zero base current, and collector turnover voltage. Measurement of base-collector short-circuit current is reduced to observing the collector current produced by a convenient known base current, the standing current being backed off in the collector-current meter; the backing-off current is controlled by a set zero device, and a meter is calibrated to read the base-collector short-circuit current (d.c.) for values of base current of 10 μA, 100 μA, 1 mA, 10 mA, and 25 mA. The d.c. collector current for zero base current is observed directly on a meter, the collector supply voltage being variable between 0 and 20 V. The collector turnover voltage is obtained by feeding the collector from a relatively high voltage through a low resistance, and facilities are incorporated to vary the feed resistance and supply voltage to give three dissipation ranges.

For simplicity, all measurements are made at d.c., frequency effects being ignored. In addition, a mains power unit is incorporated, thereby eliminating the need for battery replacement.

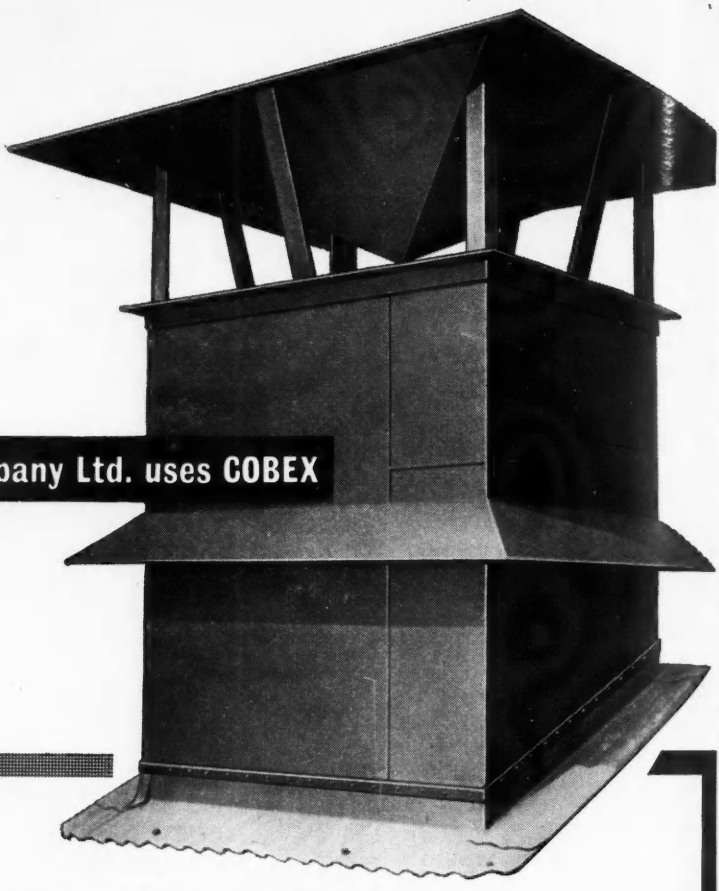
MINIATURE HIGH-ALTITUDE CONNECTORS

Three new series of miniature, high-temperature electrical connectors, possessing superior electrical characteristics, are announced by the Glendale Division of Consolidated Electrodynamics Corporation, of Glendale, California. Designed for high-altitude flight operation, the major design feature is a staggered construction which gives a long creepage path between pins, despite small connector dimensions. The body is of aluminium, anodized for corrosion resistance, each individual pin of the mated connector being surrounded by Teflon. The basic constructional features are shown in the accompanying illustration. Three different types of receptacles and a matching plug to fit all three are available. The Series "100" is a square-flange receptacle, $1\frac{1}{4} \times \frac{5}{8}$ in.; the "200" is a panel-mount receptacle, $1\frac{1}{8} \times \frac{3}{4}$ in.; and the "300" is a cord receptacle, $1\frac{1}{4} \times \frac{7}{16}$ in. With a Series "400" plug, $1\frac{1}{4} \times \frac{1}{2}$ in., any one of these connectors weighs less than an ounce.



Noise generation, snorts, and voltage drops have been avoided through a special design which provides for three separate seals, i.e., around the entering wires, around each pin connection, and at the interlocking faces, ensuring an insulation resistance of 10^4 megohms. The rear pressure seal, on each individual wire, is effected by the action of a locking nut on a pressure plate. When the connector is mated, the relatively soft Teflon inserts are forced to "cold-flow" around the pins, providing a pressure-tight seal. There are no voids to collect moisture, with no condensation to cause freezing or shorts at high altitudes. The ring pressure seal is accomplished by a small ring of Teflon near the centre of each pin. When compressed, these rings spread, causing a pressure seal between the pin and the insert. This method effectively lengthens the leakage path, since there is no direct path.

Available with 1, 3, 7, or 19 pins, these new connectors are rated for 1800 V a.c. at sea level and 800 V a.c. at 70,000 ft. They can withstand a shock of 200 *g* and show no resonance to 2000 cps. The operational temperature range is $-67°F$ to $+400°F$.



The Distillers Company Ltd. uses COBEX

British Geon Ltd., a company in the Distillers Plastics Group, have had a Cobex rigid vinyl cowl fitted to the ducting system in their Barry Works.
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NEWS OF THE MONTH

PERSONAL

The outside staff of the Salterpak Division of Geo. Salter & Co., Ltd., West Bromwich, has been increased by the appointment of **Mr. F. Blincoe** as an additional Representative for the Midland area. Mr. Blincoe, who has had considerable experience in export packing and pre-packaging with the Salterpak Division for several years, will work in association with the Division's Sales Manager, **Mr. G. R. Sanders.**

Mrs. M. Walkins has been appointed Press Relations Officer, Rubery Owen & Co. Ltd., Darlaston, in succession to **Mrs. C. Clymer.** Mrs. Walkins, an experienced journalist and an Associate of the Institute of Public Relations, was previously Publicity Officer of Auto Diesels Ltd., of Uxbridge, Middx. Her duties will include the Editorship of the Owen Organization's House Journal, " Goodwill " and the " R.O. News ", a Rubery Owen newspaper designed primarily for employees at the firm's Darlaston Works.

Mr. Norman Elce, Director and Chief Mechanical Engineer, Metropolitan-Vickers Electrical Company Limited, Manchester, has been elected a Vice-President of the Institution of Mechanical Engineers.

Mr. A. S. Dodd has been appointed Director of John Thompson Water Tube Boilers Limited and London Manager of John Thompson Limited. At the London office he succeeds **Mr. C. J. Howard,** who was recently appointed Managing Director of John Thompson Water Tube Boilers Limited. Mr. Dodds joined John Thompson at Wolverhampton five years ago from Merz and McLellan Ltd., where he was senior engineer at Newcastle-on-Tyne. At John Thompson Limited, Belfast, **Mr. James Boyd** has been appointed Area Manager, to represent all of the John Thompson Group companies in Northern Ireland and Eire.

Mr. A. C. Hazel, Managing Director of the Hurseal Heating Group has just returned from a ten day visit to the United States. During his visit Mr. Hazel attended a meeting of the American Institute of Heating and Ventilating Engineers held in Pittsburg. He was the guest of Mr. L. N. Hunter a former President of the American Institute.

Viscount Chandos, D.S.O., M.C., was re-appointed President of the British Electrical Development Association at the Association's Annual General Meeting on 7th May, 1957. **Sir Josiah Eccles, C.B.E., M.M.,** Deputy Chairman (Operation), Central Electricity Authority, and **Mr. Victor W. Dale, Companion, I.E.E.,** former Director and Secretary of E.D.A., were appointed Vice-Presidents, and **Lord Beveridge, K.C.B.,** and **Captain J. M. Donaldson, M.C.,** St. Albans, were re-appointed Vice-Presidents. At the first meeting of the new Council of the Association, **Mr. W. S. Lewis, C.B.E., J.P.,** Chairman of the Midlands Electricity Board, was elected Chairman for the year 1957–58, and **Mr. W. N. C. Clinch, M.I.E.E., F.Inst.F.,** Controller, Eastern Division, Central Electricity Authority, was elected Vice-Chairman.

Northern Aluminium Company Limited announce the following new appointments :—**Mr. J. H. Mayes,** formerly Assistant General Sales Manager, is now General Sales Manager in succession to **Mr. S. E. Clotworthy** who, as previously announced, has become Managing Director following the appointment of **Mr. Fraser W. Bruce** as President of Aluminum Company of Canada.

MR. EUGEN HOROVITZ

We announce with deep regret the death of Mr. Eugen Horovitz, Area Manager of " The Engineers' Digest " for Lancashire and Cheshire. He was 64.

We have lost in Mr. Horovitz a faithful friend and most loyal colleague, whose honesty of character and devotion to the cause which he served was well known and appreciated by the large number of engineering concerns, with whom he was in continual contact on our behalf for the past seventeen years.

In 1950 Mr. Horovitz suffered a severe heart attack. After his recovery he was living, in his Doctor's words, on borrowed time. However, he refused to retire and has carried on in his work with dauntless enthusiasm. He collapsed and died peacefully whilst visiting one of his business friends in Wythenshawe.

Mr. Horovitz will always be remembered as one of the pioneers of progress in British technical advertising.

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BUSINESS NEWS

The Industrial Truck Manufacturers' Association has recently been reconstituted so that it can constructively develop its widely increasing sphere of operation. The new **British Industrial Truck Manufacturers' Association** will meet the challenge emanating from the proposed European Free Trade Area by maintaining the prestige of United Kingdom manufacturers in the industrial truck field. Moreover it is already taking a leading part in all deliberations and activities of its counterpart associations on the continent of Europe, America and elsewhere.

Metropolitan-Vickers Electrical Co. Ltd., announces that from 29th April 1957, the postal address of the Transformer Department became Metropolitan-Vickers Electrical Co. Ltd., Transformer Department, Floats Road, Wythenshawe, Manchester 23. For cables and telexes, the Department will continue to use the Trafford Park address—Metrovick Manchester Telex 66.314.

Courtburn Positioners Limited, of Bedford, the well-known manufacturers of positioning and work-handling equipment for welding, have formed a new associated company to handle the marketing of equipment for the welding industry, other than the manufactures of the parent company. It is registered as **Courtburn Supplies Ltd.**

The associated companies of **George Ellison Ltd., and Tufnol Ltd.,** announce that from the 20th May their respective London Offices in Victoria Street, will be transferred to Ellison House, Connaught Place, London W.2. From this conveniently situated building will be conducted the southern area sales and technical service for Ellison switchgear and hydraulic valves, and for Tufnol, the non-metallic material for engineering components. The telephone number for both companies will be AMBassador 3121 (10 lines) and the telegraphic address : Starters, Telex, London (for George Ellison Ltd.) and Tufnol, Telex, London (for Tufnol Ltd.).

It was announced recently that the **Asea Company** of Vasteras, Sweden, and the **Brush Group Ltd.,** of London, have made an arrangement whereby the latter will acquire the equity of Asea Electric Limited of Walthamstow, London, also trading as **Fuller Electrical & Manufacturing Company Limited.** It is intended that the present activities of these two companies, including exclusive representation for Asea, Sweden, in the United Kingdom, will continue exactly as before but under the name of Fuller. By a licence agreement between the Fuller Company and Asea, Sweden, the former will be assured for a minimum period of ten years full participation in the technical knowledge, research and development of the Asea group of companies within the field in which the Fuller company will be active as electrical plant manufacturers. Mr. Ian Morrow and Sir George Briggs, Directors of the Brush Group will become Chairman and Vice Chairman, respectively, of the Company. Mr. Nils Plahn will remain Managing Director and there will be no change in the present management.

British Oxygen Gases Ltd., London, announce two recent patent applications in respect of their welding processes. The first relates to an improved nozzle design in gas shielded electric arc welding. A patent has been applied for which relates to the provision of thin walled tubular nozzles made of heat resisting alloys, the external dimensions of which can be much smaller without effecting the necessary conditions for welding and give a considerable improvement in the operator's vision and the ease with which the weld may be made. The second patent also relates to an improvement in gas shielded electric arc welding and relates to a means whereby this air gap may be obviated by increased velocity of the shielding gas whilst maintaining the conditions of gas flow and minimum turbulence necessary according to the nature of the weld.

Direct representation in Thailand has been established by **George Kent Ltd.,** in a drive to further increase exports into the South-East Asian area by meeting the growing demand in that country for measuring and control apparatus. A branch office and workshop has now been inaugurated in Bangkok ; it is an offshoot of the Kent subsidiary company in Penang, **George Kent (Malaya) Ltd.,** and carries that name. It is a fully equipped office offering complete technical facilities, ex-stock deliveries, and service on all Kent equipment. The address of the Bangkok branch is 284/1 Suriwongse Road.

Lancashire Dynamo Nevelin Ltd., Hurst Green, Oxted, Surrey, announce that their new telephone number is now Oxted 3361.

Under an agreement signed recently, **PacAero Inc.** of Santa Monica, California, has acquired the right to manufacture and sell the Napier " Spraymat " electrical system of de-icing in the United States, its territories and possessions for a period of 10 years. **D. Napier & Son Ltd.** is to supply all the necessary drawings, reports, technical information and assistance needed to enable PacAero to establish both manufacturing and servicing facilities, and will take all reasonable steps to promote the sale of Spraymat by PacAero. For its part, PacAero will make available to Napier details of all refinements and improvements which may result from development processes applied to the system by the American company.

English Steel Corporation Limited, of Sheffield and **Canadian Steel Foundries (1956) Limited,** a subsidiary of the Hawker Siddeley Group, have announced the formation of a new company in Canada. This new company, **Canadian Steel Wheel Limited,** will manufacture wrought steel railway wheels in Montreal.

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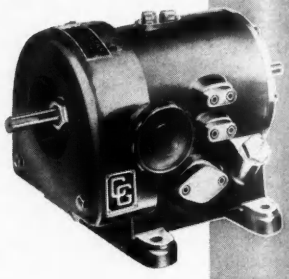

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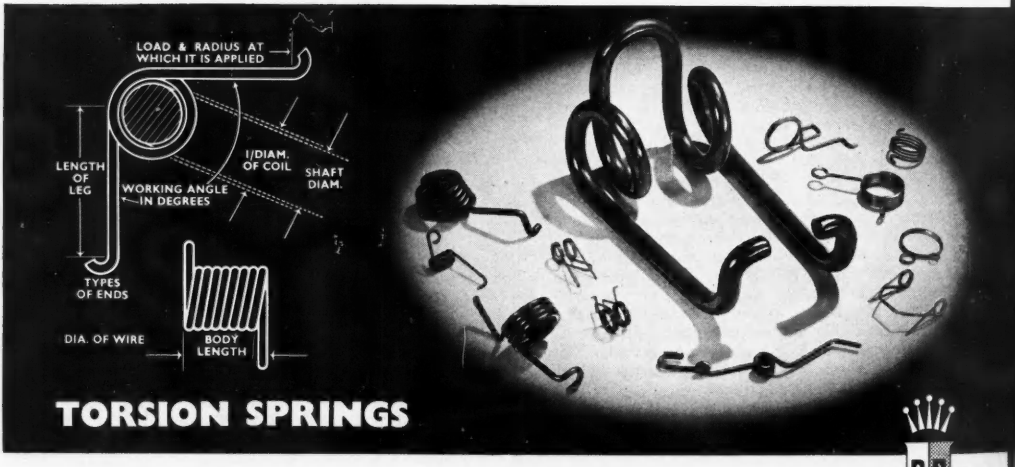

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INDUSTRIAL PRODUCTS

The new thermometer now being marketed by **Tool Treatments (Chemicals) Ltd.**, of West Bromwich, Staffs, has been specially designed to meet the needs of the plating trade and industries where steam, acids or other corrosive fumes shorten the efficiency life of a thermometer. The instrument, vapour pressure type, has a 4 in. easy read dial completely housed in a bakelite case with screw-on front. The plastic coated 6 ft capillary and bulb makes the product extremely robust with lasting efficiency. The thermometer, which can be wall mounted, has a range from 30° to 150°F.

A recent addition to the range of Sellotape self-adhesive tape products marketed by the **Industrial Sellotape Division of Gordon & Gotch Limited,** London, E.C.2, is polythene electrical tape. The tape, with a tensile strength of 16 lb per inch width, has been developed with a number of new special characteristics to provide a reliable, waterproof insulating tape, with enough elasticity to enable it to conform closely to surfaces and ensure a tight seal.

A new valve being marketed by **Stuart Davis Ltd.**, of Coventry, is poppet operated with a travel of approximately $\frac{1}{16}$ in. It is a three port valve $\frac{1}{4}$ BSP working either normally open or normally closed. The valve has full flow and will operate all single acting cylinders or pilot automatic valves for operating larger cylinders.

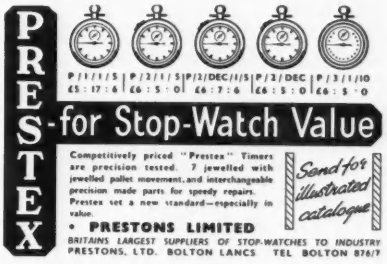
Five sizes of cast iron blowers are now available in the Breeza range manufactured by the **London Fan & Motor Co. Ltd.**, London, N.7. A leaflet is now available on these items including a performance data chart which will interest all users of power driven blowers.

New fractional horsepower induction motors, of $\frac{1}{3}$ hp and 1 hp capacity, in single phase capacitor and three phase versions, have been developed by **The General Electrical Co. Ltd.**, London, W.C.2. The motors are smaller, lighter and of more modern appearance than their predecessors, though of equivalent rating and performance. Continuously rated and fully complying with BS.170/1939, they are drip-proof, foot-mounted and available with sleeve or ball bearings, or flange-mounted with ball bearings. The motors are constructed to the dimensions of frame 66 of BS.2048/1953, " Dimensions of Fractional Horsepower Motors ", and are therefore mechanically interchangeable with other a.c. and d.c. motors complying with this specification.

The new model L.M.15 sight feed indicator manufactured by **Liquid Systems Ltd.**, of Croydon, Surrey, not only provides flexibility of liquid flow but permits control of the amount of oil or other liquid being used, and is ideal for paper mill oiling systems, steam and gas engines, sugar mill machinery and a variety of other equipment.

A new British process for soft soldering aluminium will be introduced into the United States and Canada following an agreement between the inventors, **Tiltman Langley Ltd.**, of Redhill Aerodrome, Surrey, and **Reynolds Metals Company**, of U.S.A. The "T.L. Process", which is corrosion resisting and fluxless, stems from investigations into the difficulties of soft soldering aluminium and its alloys carried out on behalf of the Ministry of Supply.

Burton, Griffiths & Co. Ltd., Birmingham, have recently become the sole distributors in the United Kingdom for " Composite " tooling as manufactured by the Liverpool Tool and Gauge Ltd. Composite tooling is in the form of combinations, in groups of two, of tools selected from six available types and a permutation of nine combinations can be obtained.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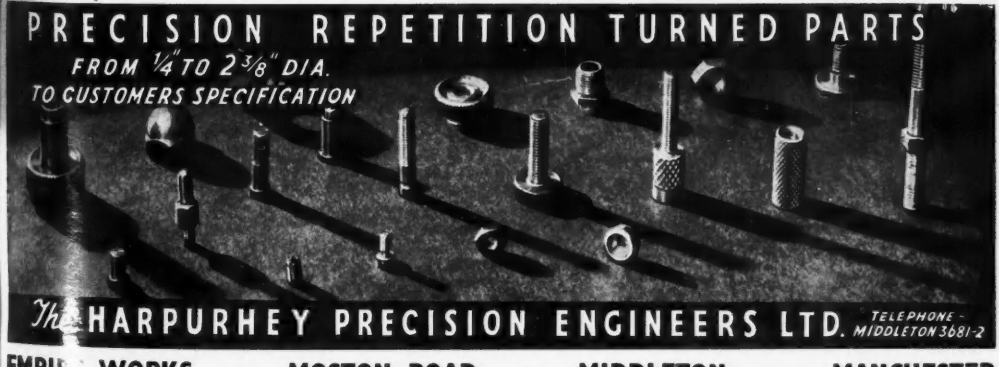
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BOOKS RECEIVED

Plant and Process Dynamic Characteristics. 258 pp., 143 illustrations. Publishers : Butterworths Scientific Publications, 88 Kingsway, London, W.C.2. Price : 50/- (postage 1/3).

During the past ten years, interest in the study of the dynamic characteristics of processes and plant has increased rapidly. As a result, and because considerable work of both a theoretical and experimental nature has been carried out, a Conference was held by The Society of Instrument Technology at Cambridge between April 4 and 6, 1956, to permit specialists in this field to discuss their results and their approach to the problems involved. This book, then, reports the proceedings of this Conference, and the papers it contains are the results of the first attempt in Great Britain to bring together for discussion those engaged in fundamental research on the dynamics of processes, measurement and control specialists, and those with practical experience of plant operation.

The objectives of research and development work in the dynamics of processes are to establish the facts concerning plants and processes ; to use the results to develop a rational basis for the prediction of the characteristics of new plant at the design stage ; and to suggest new methods of designing plant and controlling processes, so that the quality of products is improved and plant efficiency increased. These Conference papers, as reported in this interesting volume, in reflecting these objectives serve as a guide and stimulus to further research along similar promising lines.

Practical Geometry and Engineering Graphics. Sixth Edition, 1956. By W. Abbott, C.M.G., O.B.E., Ph.D., B.Sc., M.I.Mech.E. 366 pages. Publishers : Blackie & Son Limited, 17 Stanhope Street, Glasgow, C4. Price : 22/6.

This well-known work is a course in practical geometry for engineering and other students who have already received some instruction in elementary plane geometry, graph plotting, and the use of vectors. Additional material in this profusely illustrated new edition includes a section with twenty worked examples.

Mechanisms and Dynamics of Machinery. By Hamilton H. Mabie and Fred W. Ocvirk. 454 pp., 415 illustrations. Publishers : John Wiley & Sons, Inc., New York, and Chapman & Hall Limited, 37 Essex Street, London, W.C.2. Price : 68/-.

In this excellent book, the authors, both of whom are Associate Professors of Mechanical Engineering at Cornell University, U.S.A., have provided a concise, yet fully informative, treatment, covering many advanced topics, as well as elementary subject matter, in connection with the mechanisms and dynamics of machinery. As a result, more space has been made available for the discussion of such topics as analytical cam design, non-standard gearing, computing mechanisms, synthesis, and the dynamics analysis of rotating and reciprocating machinery. In addition, many examples are included, together with a generous selection of problems.

The Realities of Space Travel. Edited by L. J. Carter, A.C.I.S. 431 pp., 67 illustrations. Publishers : Putnam & Company Limited, 42 Great Russell Street, London, W.C.1. Price : 35/-.

In this interesting volume, comprising selected papers of the British Interplanetary Society, sixteen experts present the known facts about travel in outer space, outline the problems still extant, and describe how these are slowly being solved.

The whole field of space travel is covered in this book, i.e., leaving the earth and its atmosphere ; combating gravity ; the artificial satellite ; the chemical and the atom rockets ; the history of rocket development and manufacture ; interplanetary flight ; the dangers to be overcome, including meteors and cosmic rays ; human limitations ; and the probable first targets (the moon and Mars), with an analysis of their physical conditions. The twenty-four chapters provide an illuminating and comprehensive survey of space travel, its history, and future, which cannot be found elsewhere.

Inventors and Inventions. By C. D. Tuska. 184 pp., 24 illustrations. Publishers : McGraw-Hill Publishing Company Ltd., McGraw-Hill House, 95 Farringdon Street, London, E.C.4. Price : 28/-.

Intended to stimulate inventive tendencies and to further a knowledge of the psychology and methods of invention, this interesting volume shows the importance of effective protection, patenting, and marketing of inventions.

Legal terminology is kept to the barest minimum, and suggestions adaptable to the improvement of creative ability are provided in a discussion of some of the earliest inventions and discoveries, and of the effects of environment, education, and age on the inventive process. In addition, case histories of outstanding inventions are given, to illustrate methods of invention, and notable examples are given of inventions produced by various means, ranging from experiment and scientific discovery to lucky accidents.

Induction and Dielectric Heating. 206 pp., 154 illustrations. Publishers : British Electrical Development Association, 2 Savoy Hill, London, W.C.2. Price : 8/6 (postage 6d.).

This new volume, No. 6 in the " Electricity and Productivity " series of books published by the British Electrical Development Association, has been written for both technical and non-technical management executives, and undoubtedly removes much of the mystery surrounding modern methods of electrical induction and dielectric heating by showing their essential simplicity.

The book indicates how vital a part electricity plays in a wide range of new processes ; how, with the aid of dielectric heating, new uses for synthetic materials have revolutionized the conception and design of many articles in everyday use ; and how the adoption of well-chosen applications of induction heating or dielectric heating has resulted in better factory conditions, improved products, and increased productivity.

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2. **Lathes.** High-class precision lathes and shaping machines which are described in a 4-page illustrated leaflet include centre lathes on various lengths of bed, boring and facing lathes with square or hexagonal turrets, combination turret lathes, special high-production parting-off, turning, and boring lathes, copying lathes, and a 19 in. shaping machine. Each model is described briefly, while fully detailed specifications are also available.

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4. **Weights of Carbon, Alloy, and High-Speed Steels.** The 4th edition of this most useful 75-page book has now been published. Although all the weights are shown in pounds there is a good conversion table provided for metric measurements. This book is ideal for designers, engineers, and purchasing and progress staffs who have a constant need to check the weights of numerous sizes of bars, blanks, blocks, sheets, and strips.

5. **Lubricators.** An extensive range of various types of lubricators is described in a loose-leaf catalogue, which includes mechanical and displacement lubricators, gravity-feed and screw-down lubricators, together with relief valves, separators, and a hand pump. Each model is clearly illustrated, and recommendations for the selection of suitable models are included.

6. **Milling Equipment.** In addition to detailing a range of milling chucks and cutters, this 35-page book provides many pages of practical advice on the use of cutters, coolants, and lubricants, use of HSS and Stellite face mills, regrinding, settings for a cutter grinder for peripheral teeth, metal removal and rating of mills, a cutting speeds table, etc. The various cutting tools and arbors are shown in sectional line drawings, to illustrate more clearly the constructional details.

7. **Electronic Equipment.** This 8-page illustrated catalogue covers an interesting range of electronic equipment for use in both the laboratory and the production line. Written in abbreviated form, 34 instruments are covered and include a new design of metal detector which, operating from a battery supply, can be used for tracing routes and finding depths of buried pipes and cables. A similar model is also available for production flow-line observation and warning. Of great importance to industry is the automatic voltage regulator providing a constant a.c. output voltage of 230 V $\pm$ 1% for a change of load or for variations of input voltage between 170 V and 270 V, with a correction rate of 6 V per second.

8. **Aluminium in Electrical Engineering.** The primary object of this 72-page publication is to show the range of the existing applications of aluminium and its alloys and their potentialities in the electrical engineering field. At the same time, certain technical aspects are discussed in brief, in particular the rapid and successful development of jointing techniques. A brief statement on the case for aluminium, covering economic and technical factors, is followed by summaries of relevant British Standards and of the electrical, mechanical, chemical, and fabricating properties of aluminium materials for electrical uses.

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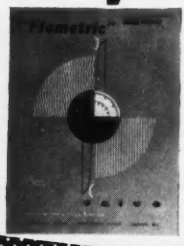

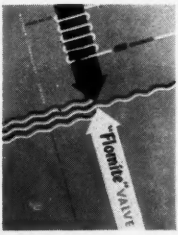

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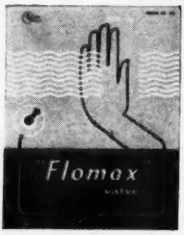

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